Hydro Environmental Ltd

Strategic Flood Risk Assessment
For Proposed
Limerick Northern Distributor Road Corridor

Variation No. 5(a)
to
Limerick County Development Plan (2010-2016)

Limerick City & County Council

February 2017

Hydrological & Environmental
Engineering Consultants

Strategic Flood Risk Assessment Of Proposed Limerick Northern Distributor Road Corridor

Variation No. 5(a) to Limerick County Development Plan (2010-2016)

Hydro Environmental Ltd
No. 4 Caiseal Riada,
Clarinbridge,
Galway,
Ireland.
Tel/Fax: 091 796734

Job No.:	205402
Report No.:	HEL205402v1.1
Prepared by:	Anthony Cawley BE, M.EngSc, CEng MIEI
Report Status	Publication
Date:	February 2017

Table of Contents

1. INTRODUCTION

Hydro Environmental Ltd was commissioned by Roughan O'Donovan Ltd on behalf of Limerick City & County Council to carry out a strategic flood risk assessment for the proposed Limerick Northern Distributor Road scheme.

The sources of information on Flood Risk along the proposed route are summarised as follows:

- OPW preliminary Flood Risk Assessment Mapping
- The JBA strategic Flood Risk Mapping (preliminary coarse mapping) of the Limerick City Area and environs for Limerick City and County Councils
- Historical Flooding Floodmaps.ie
- ESB and OPW Hydrometric Data for Shannon and Mulkear Rivers
- OPW Flood Studies update web-site portal for estimating flood flows
- Route specific Lidar data (2012)
- OSI Lidar Survey (2010)
- OPW CFRAM Lidar mapping (2011)
- OPW CFRAM River Cross-sections (2012)
- Shannon CFRAMS Inception and draft Reports
- Final Draft CFRAM mapping for the River Shannon at Limerick (June 2016)
- Hydraulics Report – Unit of Management 25/26 – June 2016 (Final)
- Hydrology Report – Unit of Management 25/26 – July 2016 (Final)
- Preliminary Options Report – Unit of Management 25/26 – July 2016 (Final)

2. DESCRIPTION OF PROPOSED ROUTE

The preferred route corridor is shown in Figure 1 commencing west of Parteen in the Knockalisheen Quinspool townland and travelling northeast to pass over the Ardnacrusha tailrace just north of Parteen Village. It then heads southeast to Cloonoughter Td. and crosses the River Blackwater and the Crummeen Canal near Cappavilla South. The proposed corridor continues southeast crossing the River Shannon floodplain and river channel and will then proceed through the areas of Ballyvollane and Mountshannon before arriving at the proposed junction location at its southern docking point. This junction will facilitate connection with the local and strategic road networks including the R445 (old Dublin Road), the M7 motorway and the National Technological Park. A further assessment area is included for consideration of a possible link road crossing of the Mulkear River.

The proposed scheme is just over 10km in length from Knockalisheen to Garraunykee and crosses river and streams of the River Shannon system. The scheme is generally not affected by tidal/coastal flooding except possibly in the vicinity of the Knockalisheen Stream in County Clare with the principal flood risk arising from fluvial (riverine) sources.

Accommodation for the LNDR scheme was made in Variation No. 3 to the Clare County Development Plan in 2015, and is confirmed by the Clare County Development Plan 2017-2023 which was adopted in December 2016.

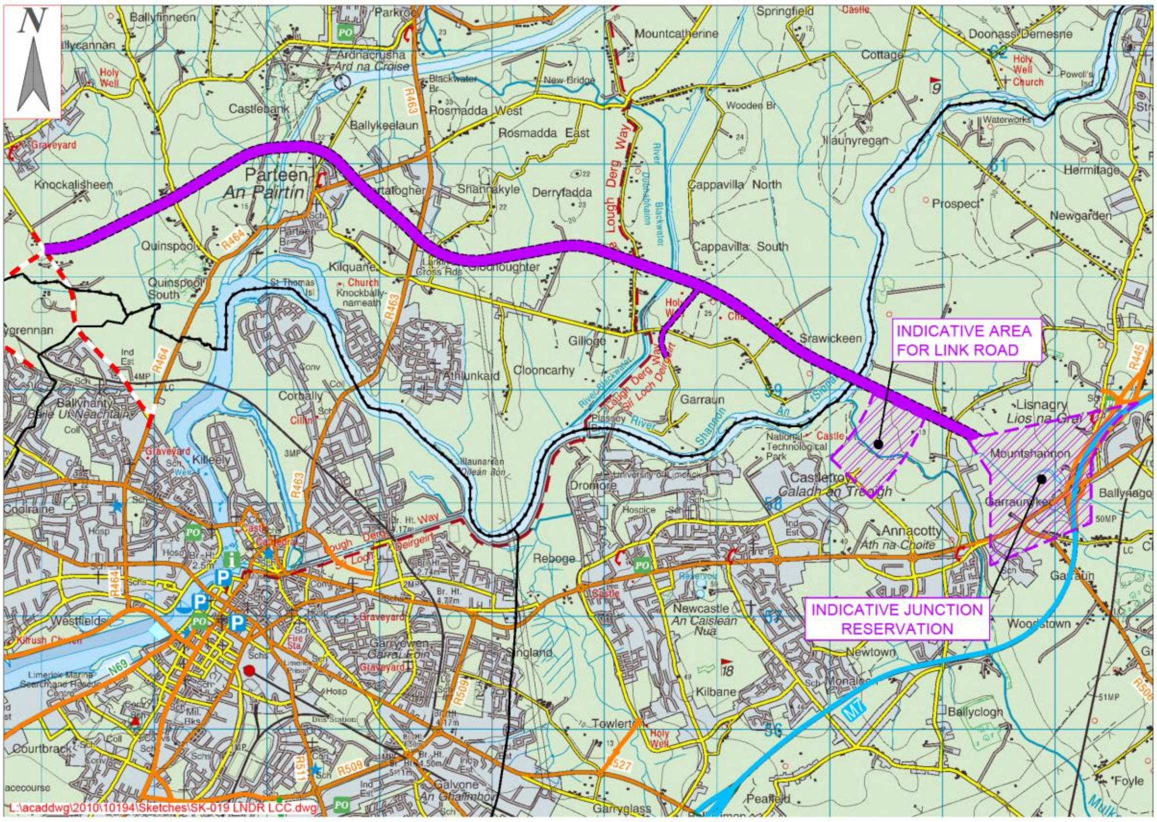

Figure 1 Proposed Limerick Northern Distributor Road Corridor and Associated Assessment Areas

3. FLOOD RISK MANAGEMENT POLICY

3.1 EU Floods Directive

The European Floods Directive 2007/60/EC on the assessment and management of flood risk aims to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. This directive applies to both inland waters and coastal waters across the whole territory of the EU.

The directive requires all member states to undertake a national preliminary flood risk assessment in order to identify areas where significant flood risk exists or might be considered likely to occur and to prepare flood hazard and flood risk maps for such areas by December 2013. The Directive required the preparation of catchment-based Flood Risk Management Plans (FRMPs), which set out flood risk management objectives, actions and measures. Catchment based flood risk management plans have been prepared for selected Flood Risk Areas throughout Ireland under the National CFRAM[1] studies. These Flood Risk Management Plans include measures to reduce the probability of flooding and its potential consequences. Implementation of the EU Floods Directive is required to be coordinated with the requirements of the EU Water Framework Directive and current River Basin Management Plans.

3.2 National Flood Policy review

3.2.1 Background

Historically management of flooding was implemented by drainage commissioners and focused on the protection and improvement of land for agricultural purposes and this is reflected in the various Drainage Acts passed (1842, 1867, 1925, 1928 and 1945).

The Brown Commission (Report of the Drainage Commission 1938-1940) which examined flooding and improvement of land through drainage resulted in the development of the Arterial Drainage Act, 1945. The Brown Commission recommended the establishment of a single national drainage authority with a remit to embark on a national drainage programme. The Office of Public Works (OPW) became the Statutory Authority responsible for implementing arterial drainage schemes nationally.

The emphasis of the 1945 act was improvement of agricultural land and following the act a priority list of river basins was set out and a programme of drainage works commenced and continued up until the early 1990's. This drainage act was amended in 1995 to allow the OPW to implement localised flood relief schemes for reliving flooding in urban areas. This amendment recognised that urban flooding had become a significant problem and signalled a departure away from arterial drainage of lands with no new arterial drainage schemes being implemented.

The various drainage districts and arterial drainage schemes, together with local flood relief schemes carried out under the drainage act continue to be maintained today by the OPW and Local Authorities.

3.2.2 Report of the Flood Policy Review Group

In 2003 a review of the National Flood Policy was carried out by a review group of relevant stakeholders. The review focuses on fluvial (river) and tidal flooding and concentrates on the roles of the state agencies in these areas. The scope of the review included the following:

- Causes, extent and impacts of the flooding problem
- Current roles and responsibilities of the main state bodies
- International best practice
- Future flood policy
- Proposals for future organisational structures and responsibilities
- Resource requirements and strategic programme

The review group prepared a report in December 2003 that was approved by government and published in September 2004. The adopted policy has many specific recommendations, including:

- Minimise the national level of exposure to flood damage through identification and management and future flood risks in an integrated, proactive and river basin based approach
- The Office of Public Works is to be the lead agency in delivering this policy
- All future expenditure in the area of flood relief will need to satisfy strict prioritisation criteria
- A two-pronged approach to flood management is to be pursued with a greater level of importance attributed to non-structural flood relief measures supported where necessary by traditional structural flood relief measures
- River basin flood management plans to be developed along with comprehensive Flood Hazard Maps and all information made available to the Dept. of the Environment, Heritage and Local Government to inform future planning and development processes

Programmes of necessary hydrological research were identified and included the update of the Flood Studies Report and river basin (hydrological) modelling, analysis of potential impact of climate change on flood frequency and severity and Meteorological forecasting

3.3 National CFRAM

The OPW is the lead agency for flood risk management and part of its responsibility is the coordination and implementation of Government Policy on the management of flood risk in Ireland. The SI No. 122 on the European Communities (Assessment and Management of Flood Risks) 2010 identifies the Commissioners of Public Works as the competent authority with overall responsibility for the implementation of the Floods Directive (2007/60/EC).

In order to comply with the Floods Directive (2007) and the National Flood Policy Review Group (2004) a national Catchment Flood Risk Assessment and Management (CFRAM) programme commenced in 2011 and flood risk and hazard mapping completed in 2015 and the catchment management plans and the Strategic Environmental Assessment (SEA) process completed in 2016. This followed preparatory studies involving the Preliminary Flood Risk Assessment mapping and AFA (areas for further assessment) identification and followed a number of Pilot Catchment studies including the Lee Catchment FRAMS (commenced 2006), the River Dodder FRAMS (commenced 2007) and the Fingal East Meath FRAMS (commenced 2008) to refine the approach and methodologies to be adopted. The areas deemed to be at significant risk are identified as AFAs and more detailed assessment on the extent and degree of flooding was undertaken in the CFRAM studies and involved detailed survey hydrological and hydraulic modelling, flood mapping, preparation of flood risk management plans and supporting Strategic Environmental Assessments.

3.4 Planning Guidelines Concerning Flood Risk Management

3.4.1 Background

In November 2009, the OPW and DoEHLG jointly published the Planning System and Flood Risk Management - Guidelines for Planning Authorities which are aimed at ensuring a more consistent, rigorous and systematic approach to fully incorporate flood risk assessment and management into the planning system.

The core objectives set out in these guidelines are to:

- Avoid inappropriate development in areas of flood risk
- Avoid new developments that may increase flood risk elsewhere
- Ensure effective management of residual risks for developments permitted in floodplains
- Avoid unnecessary restriction of national, regional or local economic growth
- Improve the understanding of flood risk among the relevant stakeholders

- Ensure that the requirements of EU and National law in relation to the natural environment and nature conservation are compiled with at all stages of flood risk management.

The key principles to be adopted by regional and local authorities, developers and their agents are to:

- Avoid the risk, where possible
- Substitute less vulnerable uses, where avoidance is not possible
- Justify that the need for the development is a strategic need, where avoidance and substitution are not possible
- Mitigate and manage the risk

<u>Decision Making Process</u>

Management of flood hazard and potential risks in the planning system is based on:

1. Sequential Approach
2. Justification Test

3.4.2 Sequential Approach

The aim of the sequential approach is to guide new development away from areas at risk from flooding into areas at low risk of flooding. The approach makes use of flood risk zones and classifications of vulnerability of property to flooding but ignores the presence of flood protection structures. The sequential approach should be applied to all stages of the planning process, particularly at the plan making stage.

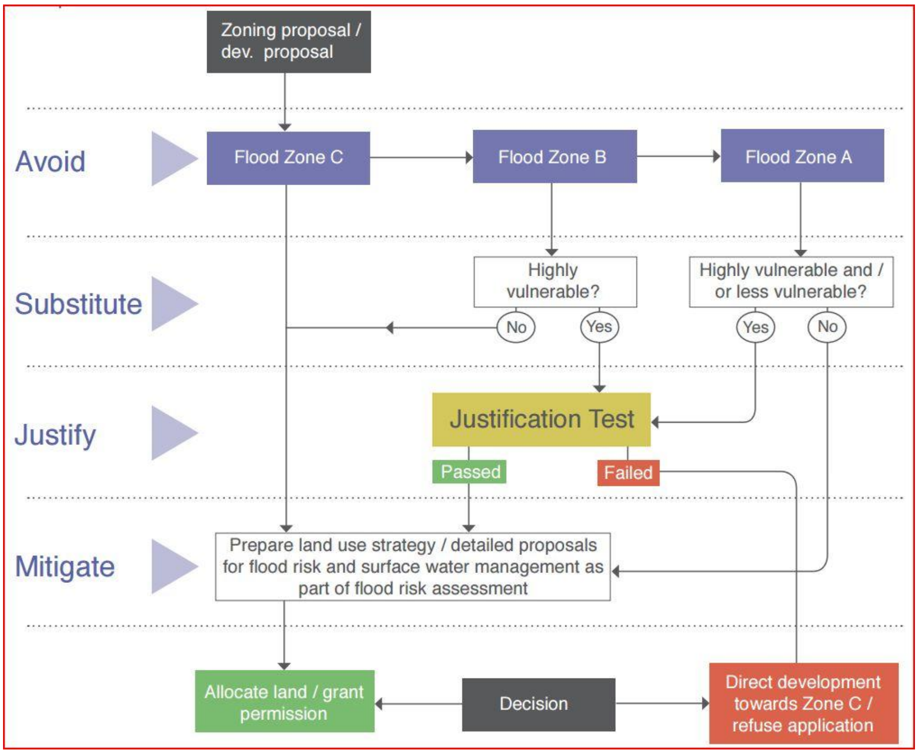

Figure 2 Sequential approach mechanism in the planning process (Fig. 3.2 from the Flood Risk Management Planning Guidelines)

The Sequential Approach is based on the following principles:

AVOID

Preferably choose lower flood risk zones for new developments

SUBSTITUTE

Ensure proposed development type is not especially vulnerable to the adverse impacts of flooding

JUSTIFY

Ensure that the development being considered is for strategic

MITIGATE

Ensure that flood risk is reduced to acceptable levels

PROCEED

Only where Justification Test passed. Ensure emergency planning measures are in place.

3.4.3 Flood Risk Zones

Definitions of flood risk zones in the planning guidelines are based on probability of occurrence with defined three flood risk zones (High, Moderate and Low). These flood zones are as follows:

- Zone A High Probability – Highest risk of flooding: More than 1% probability of river flooding and more than 0.5% probability of tidal flooding. Development should be avoided and/or only considered through application of a justification test. Most types of development would be considered inappropriate in this zone. Development in this zone should be avoided and/or only considered in exceptional circumstances, such as in city and town centres, or in the case of essential infrastructure that cannot be located elsewhere, and where the justification test has been applied.

- Zone B Moderate Probability: Between 1 and 0.1% probability of river flooding or between 0.5 and 0.1% probability of coast flooding. Development should only be considered in this zone if adequate land or sites are not available in Zone C or if development in this zone would pass the Justification Test. Highly vulnerable development would generally be considered inappropriate in this zone, unless the requirements of the Justification Test can be met. Less vulnerable development and water-compatible development might be considered appropriate in this zone. In general however, less vulnerable development should only be considered in this zone if adequate lands or sites are not available in Zone C and subject to a flood risk assessment to the appropriate level of detail to demonstrate that flood risk to and from the development can or will adequately be managed.

- Zone C Low Probability: Less than 0.1% probability of river or coastal flooding. Development in this zone is appropriate from a flood risk perspective (subject to assessment of flood hazard from sources other than rivers and the coast) but would need to meet the normal range of other proper planning and sustainable development considerations.

These flood zones are determined on the basis of the probability of river and coastal flooding only and should be prepared by suitably qualified experts with hydrological experience. The derivation of these zones is broadly in line with those in common usage internationally. They are based on the current assessment of the 1% and the 0.1% fluvial events and the 0.5% and 0.1% tidal events, without the inclusion of climate change factors.

The provision of flood protection measures in appropriate locations, such as in or adjacent to town centres, can significantly reduce flood risk. However, the presence of flood protection structures should be ignored in determining the flood zones. This is because areas protected by flood defences still carry a residual risk of flooding from overtopping or breach of the defences and the fact that there may be no guarantee that the defences will be maintained in perpetuity. The likelihood and extent of this residual risk needs to be considered, together with the potential impact on proposed uses, at both development plan and development management stages, as well as in emergency planning. The finished floor levels within protected zones will need to take account of both urban design considerations and the residual risk remaining.

3.4.4 Development Type Vulnerability Classification

In determining the suitability of the Development within the various flood zones the vulnerability class of the development is taken into consideration. Three categories of vulnerability are considered as described in Table 1 and 2 below:

Table 1 Classification of Vulnerability of Different Types of Development

Vulnerability Class	**Land uses and types of development which include*:**
Highly Vulnerable development (including essential infrastructure)	• Garda, ambulance and fire stations and command centres required to be operational during flooding • Hospitals • Emergency access and egress points • Schools; • Dwelling houses, student halls of residence and hostels • Residential institutions such as residential care homes, children's homes and social services homes • Caravans and mobile home parks • Dwelling houses designed, constructed or adapted for the elderly or, other people with impaired mobility • Essential infrastructure, such as primary transport and utilities distribution, including electricity generating power stations and sub-stations, water and sewage treatment, and potential significant sources of pollution (SEVESO sites, IPPC sites, etc.) in the event of flooding
Less Vulnerable development	• Buildings used for: retail, leisure, warehousing, commercial, industrial and non-residential institutions • Land and buildings used for holiday or short-let caravans and camping, subject to specific warning and evacuation plans • Land and buildings used for agriculture and forestry • Waste treatment (except landfill and hazardous waste) • Mineral working and processing • Local transport infrastructure
Water Compatible development	• Flood control infrastructure • Docks, marinas and wharves • Navigation facilities • Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location; Water-based recreation and tourism (excluding sleeping accommodation) • Lifeguard and coastguard stations • Amenity open space, outdoor sports and recreation and essential facilities such as changing rooms • Essential ancillary sleeping or residential accommodation for staff

Vulnerability Class	**Land uses and types of development which include*:**
	required by uses in this category (subject to a specific warning and evacuation plan)
	• Uses not listed here should be considered on their own merits

Table 2 Requirement for Justification Test based on Vulnerability group and Flood Zone Category

Vulnerability Class	**Flood Zone A**	**Flood Zone B**	**Flood Zone C**
Highly Vulnerable development (including essential infrastructure)	Justification Test	Justification Test	Appropriate
Less Vulnerable development	Justification Test	Appropriate	Appropriate
Water Compatible development	Appropriate	Appropriate	Appropriate

3.4.5 Justification Test

Further sequentially based decision making should be applied when undertaking the Justification Test for development that needs to be in flood risk areas for reasons of proper planning and sustainable development:

1. within zone or site, development should be directed to areas of lower flood probability
2. where impact of the development on adjacent lands is considered unacceptable the justification of the proposal or zone should be reviewed
3. where the impacts are acceptable or manageable, appropriate mitigation measures within the site and if necessary elsewhere should be considered.

A justification test is required where a planning authority is considering the future development of areas at a high or moderate risk of flooding, for uses or development vulnerable to flooding that would generally be inappropriate as set out above within the flood zones. In such cases the planning authority must be satisfied that it can clearly demonstrate on a solid evidence base that the zoning or designation for development will satisfy the justification test outline in Box 4.1 of the guidelines as presented below in Plate 1.

Box 4.1: Justification Test for development plans

Where, as part of the preparation and adoption or variation and amendment of a development/local area plan[1], a planning authority is considering the future development of areas in an urban settlement that are at moderate or high risk of flooding, for uses or development vulnerable to flooding that would generally be inappropriate as set out in Table 3.2, all of the following criteria must be satisfied:

1. The urban settlement is targeted for growth under the National Spatial Strategy, regional planning guidelines, statutory plans as defined above or under the Planning Guidelines or Planning Directives provisions of the Planning and Development Act, 2000, as amended.

2. The zoning or designation of the lands for the particular use or development type is required to achieve the proper planning and sustainable development of the urban settlement and, in particular:

   (i) Is essential to facilitate regeneration and/or expansion of the centre of the urban settlement[2];

   (ii) Comprises significant previously developed and/or under-utilised lands;

   (iii) Is within or adjoining the core[3] of an established or designated urban settlement;

   (iv) Will be essential in achieving compact and sustainable urban growth; and

   (v) There are no suitable alternative lands for the particular use or development type, in areas at lower risk of flooding within or adjoining the core of the urban settlement.

3. A flood risk assessment to an appropriate level of detail has been carried out as part of the Strategic Environmental Assessment as part of the development plan preparation process, which demonstrates that flood risk to the development can be adequately managed and the use or development of the lands will not cause unacceptable adverse impacts elsewhere.

   N.B. The acceptability or otherwise of levels of any residual risk should be made with consideration for the proposed development and the local context and should be described in the relevant flood risk assessment.

Plate 1 Justification Test for development plans

3.4.6 Flood Risk Assessment

A staged approach to flood risk assessment that covers both the likelihood of flooding and the potential consequences is recommended in carrying out a Flood Risk Assessment (FRA). The stages of appraisal and assessment are:

Stage 1 Flood Risk Identification

Stage 2 Initial Flood Risk Assessment

Stage 3 Detailed Flood Risk Assessment

Stage 1 Flood risk identification – to identify whether there may be any flooding or surface water management issues related to either the area of regional planning guidelines, development plans and local area plans (LAPs) or a proposed development site that may warrant further investigation at the appropriate lower level plan or planning application levels.

Stage 2 Initial flood risk assessment – to confirm sources of flooding that may affect a plan area or proposed development site, to appraise the adequacy of existing information and to scope the extent of the risk of flooding which may involve preparing indicative flood zone maps. Where hydraulic models exist the potential impact of a development on flooding elsewhere and of the scope of possible mitigation measures can be assessed. In addition, the requirements of the detailed assessment should be scoped.

Stage 3 Detailed flood risk assessment – to assess flood risk issues in sufficient detail and to provide a quantitative appraisal of potential flood risk to a proposed or existing development or land to be zoned, of its potential impact on flood risk elsewhere and of the effectiveness of any proposed mitigation measures.

All stages may not be needed in the FRA in order to inform the decision making process and often a Stage 2 assessment is sufficient at the strategic level to inform the decision making process. This will depend on the level of risk, the level of conflict with the proposed development and the scale of mitigation measure being proposed. For the purposes of applying the sequential approach, once a flood risk has been identified it can be avoided. Where development is planned in flood risk areas, a detailed assessment may be carried out within the FRA, so that the potential for development of the lands and their environmental and flood impact can be assessed.

The Flood Risk Assessment for the Northern Distributor Road Development carried out to support Variation No. 5(a) to Limerick County Development Plan (2010-2016) will:

- Identify the nature of flood risk (type and source) within the study area of the LNDR in county Limerick
- Provide an improved understanding of flood risk issues along the proposed alignment within County Limerick
- Assess the flood risk to the LNDR associated with the proposed River Shannon Crossing and a Link Road Crossing of the Mulkear at Castletroy.
- Assess the potential Flood impact of the LNDR
- Apply Sequential and Justification test to the LNDR

4. CLIMATE CHANGE AND FLOOD RISK

4.1 Introduction

There is a high degree of uncertainty in relation to the potential effects of climate change, and therefore a precautionary approach is required. Examples of precautionary approach include:

- Recognising that significant changes in the flood extent may result from an increase in rainfall or tide level and accordingly adopting a cautious approach to zoning lands in these potential transitional areas.

- Ensuring that the finish levels of structures are sufficient to cope with the effects of climate change over the life time of the development.

- Ensuring that structures to protect against flooding (e.g. defence walls) are capable of adaptation to the effects of climate change when there is more certainty about the effects (e.g. foundations of flood defence designed to allow future raising of flood wall to combat climate change).

4.2 Climate Change Allowance for Fluvial Flood Flows

Climate change scenarios suggest for UK and Ireland fluvial floods in the 2080's increasing by up to 10% (low and medium low scenarios) or by up to 20% (medium high and high scenarios). Present recommendations are to include in the design flow a 20% increase in flood peaks over 50 years return period as a result of climate change. This scenario based on the Irish growth curve will result in a present day 100 year flood becoming a 25-year flood in approximately 50 years time. The extent and expected levels of flooding are derived based on these flows.

Other predicted climate change effects for the UK are:

- A 4mm to 5 mm per annum rise in mean sea level
- Additional intensity of rainfall of 20%
- An additional 30% Winter rainfall by the 2080's
- A reduction of 35%/45% rainfall in Summer
- The 1 in 100 year rainfall storm to increase by 25%

<u>DEFRA Guidance</u>
In the UK research is ongoing to assess regional variations in flood allowances and the rate of future change. Current research thus far does not provide any evidence for the rate of future change let alone consider regional variations in such a rate. The UK Flood and Coastal Defence Appraisal Guidance (DEFRA, 2006) gives the climate change ranges as

per Table 1 below and as a pragmatic approach it is suggested that 10% should be applied up to 2025, rising to 20% beyond 2025.

In Ireland general practice is to use a medium range climate change allowance for flood flows of 20% over the next 100 years. This rate has been adopted by the OPW for all of its Catchment Flood Risk Assessment and Management Studies (Lee, Dodder, Tolka CFRAMs, Shannon, West, etc.).

UK Flood and coastal appraisal guidance (DEFRA, 2006)				
Parameter	**1990 – 2025**	**2025 - 2055**	**2055 - 2085**	**2085 - 2115**
Peak rainfall intensity (preferably for small catchments)	+5%	+10%	+20%	+30%
Peak river flow (preferably for larger catchments)	+10%	+20%		

Table 3 UK flood and coastal defence appraisal guidance (DEFRA, 2006)

4.3 Sea level rise

Scientists predict that global sea level rise will have two main causes. Firstly, as the oceans heat up the water expands. At present this thermal expansion accounts for about half of the observed increase in sea level. The other cause is melting land ice from glaciers and ice caps. The rate of melt and the volumes of water locked within these sources are uncertain and this is a cause for concern.

In recent years, ice shelves have broken off huge ice sheets in Antarctica and Greenland. The ways in which they are melting is only now beginning to be understood fully enough to allow estimates of how fast this melt is occurring and how much this will affect sea levels. If they melt as fast as is now thought to be possible, sea levels could rise dramatically over the next century, flooding many of the world's major cities and much of the world's most productive farmland. Consequently, guidance on sea level rise allowances for flood risk management is continually changing as more scientific research is published with allowances likely to increase as opposed to decrease in future years.

The biggest threat to coastal flood risk areas is from sea level rise. Global mean sea levels are predicted to increase from a combination of thermal expansion of the water column and melt from the glaciers and reduction of liquid water storage on land. The Intergovernmental Panel on Climate Change Third Assessment Report (*IPPC TAR)* that preceded the published *IPCC Fourth Assessment Report* (2007) has been used as the basis of future sea level projections for Ireland. A best estimate increase of 480 mm to year 2100 has been suggested by Sweeney et al (2003) and used in the *Greater Dublin Strategic Drainage Study* (GDSDS 2005). This value was not directly challenged in the 2007 *IPCC* report, with a range of 0.2 - 0.51 m given for the prudent Medium-High A2 emission scenario.

The UK DEFRA (2006) publication suggests for the UK and globally that significantly higher rates of sea level rise, particularly towards the end of the century, than the 500mm allowance that is currently considered.

Table 4 The UK Flood and Coastal Defence Appraisal Guidance (DEFRA, 2006) Regional Net Sea Level Rise Allowances

Region	Assumed vertical land movement (mm/yr)	Net Sea-Level Rise (mm/yr)				Previous Allowances
		1990-2025	2025-2055	2055-2085	2085-2115	
East of England	-0.8	4.0	8.5	12.0	15.0	6mm/yr constant
South West and Wales	-0.5	3.5	8.0	11.5	14.5	5mm/yr constant
NW & NE England, Scotland	+0.8	2.5	7.0	10.0	13.0	4 mm/yr constant

The latest IPCC fifth Assessment Report (2014) has investigated the current and future trends in global mean sea level rise (GMSLR) and have concluded with a high level of confidence under various emission scenarios considered (four modelled RCPS (Representative Concentration Pathways) that thermal expansion of the sea due to warming will increase Global mean sea level by between 0.15 to 0.3m by 2100. This report predicts at medium confidence the contribution of glacier mass loss to GMSLR for the four RCP scenarios. The global glacier volume is projected to decrease by 15 to 55% for RCP2.6, and by 35 to 85% for RCP8.5 and in between these rates for the other two RCP scenarios. RCP2.6 is representative for scenarios leading to very low greenhouse gas concentration level, it is a so called “peak” scenario with radiative forcing reaching a peak level of 3.1 W/m^2 mid-century and returning back to $2.6W/m^2$ by 2100. RCP8.5 is characterised by increasing greenhouse gas emissions overtime leading to high greenhouse gas concentrations by 2100.

Projections of GMSLR by 2100 under the high RCP8.5 scenario are 0.53 to 0.98m with rises of 8 – 16mm/annum during 2081 to 2100 and under the low RCP2.6 scenario are a rise is 0.28 to 0.61mm.

Observations of GMSLR show that from 1901 to 1990 1.5mm per annum mean rise and from 1993 to 2010 the mean rise was 3.2mm per annum.

The IPCC concluded that it is very likely that sea level will rise in more than about 95% of the ocean area. About 70% of the coastlines worldwide are projected to experience sea level change within 20% of the global mean sea level change. GMSLR during 1901–2010 can be accounted for by ocean thermal expansion, ice loss by glaciers and ice sheets, and change in liquid water storage on land. It is very likely that the 21st-century mean rate of GMSLR under all RCPs will exceed that of 1971–2010, due to the same processes. It is virtually certain that global mean sea level rise will continue for many centuries beyond 2100, with the amount of rise dependent on future emissions.

The Irish Coastal Protection Strategy Study prepared by RPS on behalf of the OPW (RPS, 2010) uses a Mid-Range Future Scenario (MRFS) reflecting changes that are within the typical range projected for mean sea level rise of 500mm. The glacial isostatic adjustment for land movement along the west coast is projected to be very minor. An allowance of 500mm mean sea level rise to the year 2100, which accounts for a 500mm increase in mean sea level and no increase for isostatic land movement adjustment was included in that study to simulate a potential mid-range future climate change scenario.

The Flood Risk Planning Guidelines recommends a precautionary approach to climate change effects in respect to flooding due to the high level of uncertainty in predicting its effects. It recommends the following in this respect:

- Caution in zoning lands in these potential transitional areas that would be impacted if climate change predictions occur
- Ensuring that the level of structures designed to protect against flooding are sufficient over the lifetime of the design to cope with the effects of climate change
- Ensuring that structures to protect against flooding and the development are capable of adaption to the effects of climate change when there is more certainty as to the effects

Notwithstanding the above precautionary principle, the flood risk zones defined in the Flood Risk Planning Guidelines are based on the present-day assessment of the 100 year (1%) and 1000 year (0.1%) return period for fluvial flooding and the 200 year and 1000 year for tidal flooding. The OPW provide specific guidance as to the allowances in their publication entitled “Assessment of Potential Future Scenarios, Flood Risk Management Draft guidance, 2009 and these allowances are summarised in Table 5.

Table 5 Climate Change Allowances for Future Scenarios 100 year

Criteria	**Mid-Range Future Scenario MRFS**	**High-End Future Scenario HEFS**
Mean Sea Level Rise	+500mm	+1000mm
Land Movement	-0.5mm/year	-0.5mm/year
Extreme Rainfall Depths	+20%	+30%
Flood Flows	+20%	+30%

4.4 Summary

The recommended climate change allowance in respect of impact assessment and setting of safe finish levels is based on the medium range scenarios of 20% fluvial flood increase and 0.5m sea level rise plus adjustment for isostatic tilting of the land mass. Such an approach meets the current OPW practices in respect to Section 50 approval and CFRAM mapping.

For the purposes of this SFRA there are no coastal Flood risk source associated with the LNDR corridor within the Limerick County Jurisdiction. For the purposes of inclusion of Climate change the 1000 year flow and flood level projections with used to represent the 100year flood with climate change. In respect to Flood Risk Zones and in keeping with the Flood Risk Management Planning guidelines the flood risk zones A, B and C are defined based on present day estimates of the 100year and 1000year flood levels.

5. HYDROLOGY OF PROPOSED ROUTE

The streams and river catchments intercepted by the proposed LNDR D Route Corridor are presented in Figures 2.1 to 2.3. The characteristics of these watercourses are summarised below:

1. Knockalisheen Stream (CH +0750) - minor stream of 4.3 km^2 running off hill slopes to the north having an estimated 100year flood flow of 6.5cumec representing a discharge rate of 1.5cumec per km^2. This stream outfalls to the River Shannon at Quinspool South, just downstream of Corbally Weir and the tailrace confluence with the River Shannon, and discharges to the estuarine section of the River Shannon. The lower reaches of this stream are tidal during spring tides and the lower reaches are susceptible to flooding from backwatering by the Shannon.

2. Parteen (aka Ballyfinneen) Stream (CH +2055) – Minor Stream of 2.75km^2 catchment running off the local hill slopes at Ballycar South - This stream outfalls to the Ardnacrusha Tail Race near Parteen. The estimated 100year design flood flow is 5.1cumec representing high runoff rates of 1.85cumec per km^2.

3. Coolmallira Stream (CH +2280) – minor Stream Discharges to the Ardnacrusha Tail Race at Parteen having a catchment area of 3km^2. The 100year design flow for this stream is estimated to be 4.5cumec.

4. Ardnacrusha Tailrace (CH +2380) Engineered channel cut into bedrock designed to convey in excess of 400cumec from the River Shannon. The proposed crossing corridor is located 1440m upstream of its confluence with the River Shannon at Quinspool and 720m downstream of the Ardnacrusha Power Station. A typical cross-section of the tailrace channel is presented in Figure 3.

5. Two minor local streams/drains (CH +4560 and 4880) immediately to the East of Parteen at Rosmadda West and Ballykeelaun having respective catchment areas of 1.2 km^2 and 0.8 km^2. These are localised flat catchments having little potential for flooding. The estimated 100year flood flows for these streams are 1.8 and 1.2cumec respectively. These flow magnitudes are small and easily accommodated using a small Box Culvert section. This represents flood runoff rates of approx 1.5cumec per km^2.

6. River Blackwater (CH +6200) – small river of some 61.5km^2 catchment to the proposed corridor. This river passes under the Ardnacrusha Headrace channel and has a moderately steep catchment draining the southeast slopes of the Knockanuarha / Seefin mountain range. The estimated median Flood Flow at the road crossing is c. 23 cumec and the 100year Flood is c. 39 cumec using the FSU method. The 100year flood flow estimate represents runoff rates of 0.64 cumec per km2 and would not be considered excessive given its steep and impervious upper catchment area. Existing bridges including the Ardnacrusha headrace Aquaduct are single span

structures with no provision for overbank conveyance. These structures vary in opening size from the aquaduct culvert, which is c. 5m wide by 4m high arch to masonry road bridges 8 to 10m in width and 4 to 5m in height.

7. Errina Canal (CH +6240) represents an old navigation channel with six locks that ran from Errina to Plassey and which ran alongside the Blackwater channel in its lower reach. This canal does not have a very extensive drainage catchment and the River Shannon supplies a water feed to the channel.

8. Shannon Floodplain tributary stream (CH +7640) small floodplain stream that conveys runoff waters to the River Shannon from a catchment area of 1.6km^2. The estimated 100year flood flow in this stream/drain is 1.6cumec which can easily be accommodated using a box section under the road embankment.

9. River Shannon (CH +8080) has a catchment area to the road crossing of some 10,854km^2. This section of the River is controlled by the ESB who divert flow away from the Shannon down through the Ardnacrusha Headrace. The natural (without diversion) annual flood rate at the River Crossing point is estimated to be 355cumec the 100year to be 661cumec and the 1000year to be 827cumec based on calculations using the OPW FSU[1] method. Based on gauged information the FSU[1] method significantly underestimates the total flood flow within the River Shannon system.

   The CFRAM study carried out by Jacobs Consulting Engineers estimates the 10year flood flow in the River Shannon to be 330cumec, the 100year to be 524cumec and the 1000year to be 714cumec which allows for diverted flow down through Ardnacrusha. The CFRAM flow estimates downstream of the Mulkear confluence is a 10year of 419.3cumec, 100year of 638cumec and a 1000year of 856cumec.

   Statistical analysis of 84years of ESB measured annual maximum daily flood flows obtained from the ESB for the River Shannon (total flow that includes Ardnacrusha canal and River Shannon flows combined) indicate a median Flood Flow of 534cumec, 100year of 877cumec and a 1000year of 1074cumec. The Ardnacrusha channel and power station has a maximum flow capacity of 400cumec but during flood conditions due to the drawdown effects at the Parteen Spill Gates the maximum discharge to the Ardnacrusha Headrace is only approximately 350 to 360cumec. Applying a diverted flow of 360cumec the return period Shannon flood flows downstream of Parteen weir are estimated to be 517cumec and 714cumec for the 100year and 1000year return periods respectively.

   To the east of the Shannon Crossing location, lands in the vicinity of Mountshannon Road have historically been subjected to flooding. This flooding derives from the River Shannon and also the combined influences of the Shannon and Mulkear River systems. The Mulkear River is a big factor on flooding of the Mountshannon and Annacotty areas.

10. Consideration is being given to provide a link crossing of the Mulkear River and floodplain near Castletroy to tie-in to the National Technological Park and R445. The Mulkear River has a catchment area to the Crossing of 655km^2. The OPW Flood Studies Update (FSU) flood flow estimation method estimates 100year and 1000year flood flows of 235cumec and 290cumec. The Mulkear catchment is just over 6% of the Shannon Catchment area to Parteen Weir and is considerably flashier with the 100year peak flows almost 29% of the total River Shannon 100year flow which includes the diverted flow. Combination of fthe peak flood flows in the Shannon and Mulkear at Castletroy is very unlikely at the extreme events with the Shannon being much slower and responding to long duration rainfall events whereas the Mulkear's response is reasonably fast relative to the Shannon therefore unlikely that the more extreme flood events would coincide.

    The Link corridor under consideration crosses a wide floodplain area of almost the entire length of the corridor between the mainline LNDR and the R445 road. On the right (Northeast) bank this flood plain is open, unprotected and conveys the Mulkear Flood waters to the Shannon channel. On the Left (Southwest) bank the lands are part of the IDA National Technological Park and are protected by a flood embankment which prevents the Mulkear flood waters from naturally flowing through these lands on-route to the River Shannon. These protected lands naturally back-up and flood during prolonged River Shannon flooding. These lands are flooded from the Shannon downstream and by the backing-up of local drainage waters unable to discharge to the Shannon due to prolonged period of elevated water levels in the Shannon. Therefore, the Floodplain lands of the Mulkear are important at the proposed Link corridor. The right bank for flood conveyance of the Mulkear flood flows and the protected Left Bank for local flood storage. The Mountshannon Road area is susceptible to flooding from the Mulkear which can during the larger flood events flood northwards along the Mountshannon Road towards the River Shannon Floodplain and can potentially backwater the Thornfield Stream where it crosses under the Mountshannon Road. This northwards Flow path for the Mulkear Flood waters is important and the proposed River Shannon LNDR corridor should maintain this flow path.

11. Thornfield Stream Mountshannon (CH +9740) is a minor stream that flows into the Mulkear River at Castletroy. The catchment area is 5.4km2 and is moderately flat. The estimated 1000year flood flow rate for the stream at the road crossing is 3.2cumec. This is a reasonably steep local stream which discharges to the Mulkear River a short distance downstream of the Mountshannon road. The CFRAM study has identified a potential for this stream upstream of the Mountshannon road to flood low-lying lands to the North. Undersized culverts under the Mountshannon road have been identified which in flood conditions will become surcharged and overtop its bank and road.

The Watercourses of relevance to the proposed Variation No. 5(a) of the Limerick County Development Plan are the River Shannon (ref 9.) the Mulkear River (ref 10.) and the Thornfield Stream at Mountshannon (Ref 11). The other watercourses (ref 1 to 8) are located to the West and North of the River Shannon and are located within in the Clare County Development Area.

[1] *FSU - Flood Studies Update (OPW 2014)*
[2] *CFRAM Catchment Flood Risk Assessment and Management*

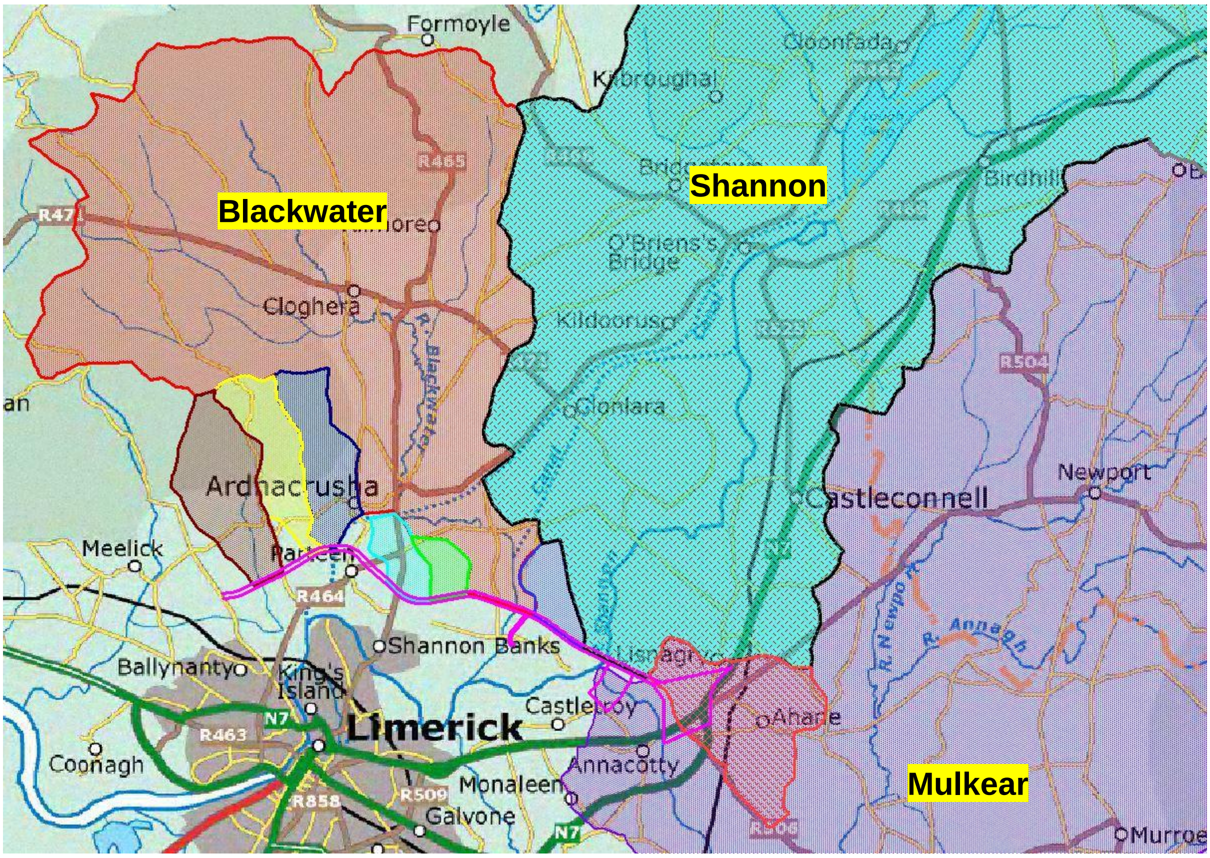

Figure 2.1 Catchment Map showing proposed LNDR corridor

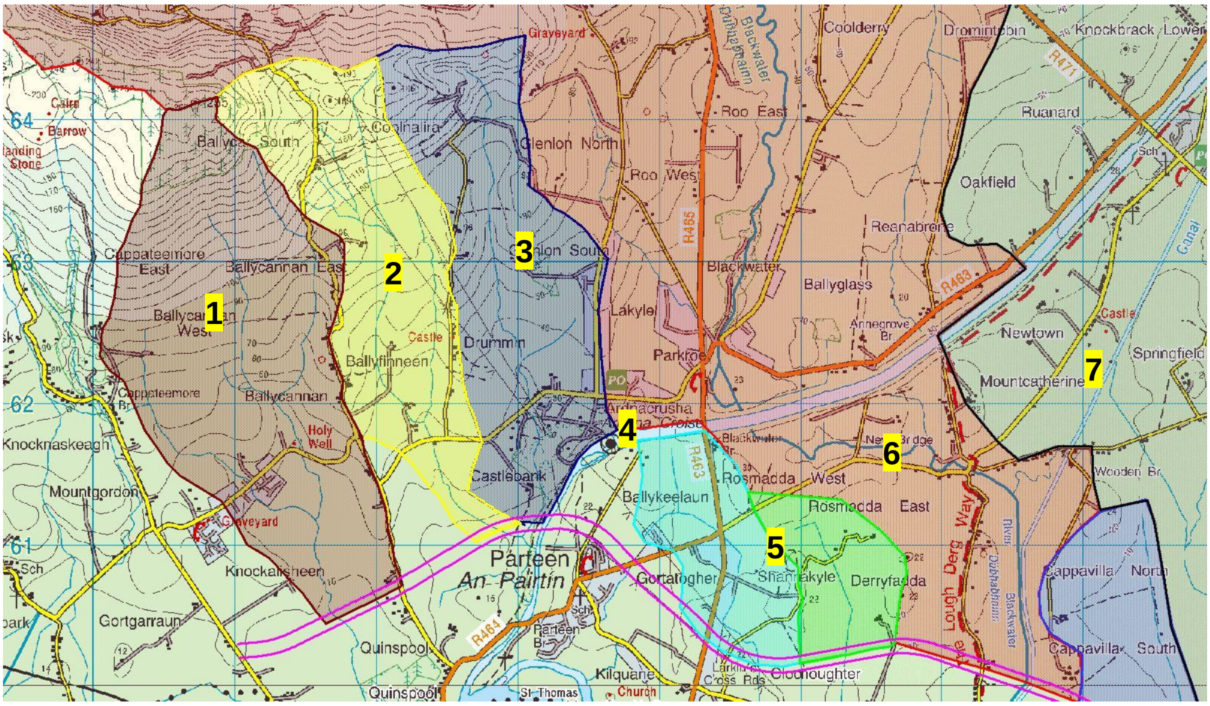

Figure 2.2 Catchment Map (Part 1) showing smaller watercourses and proposed LNDR corridor

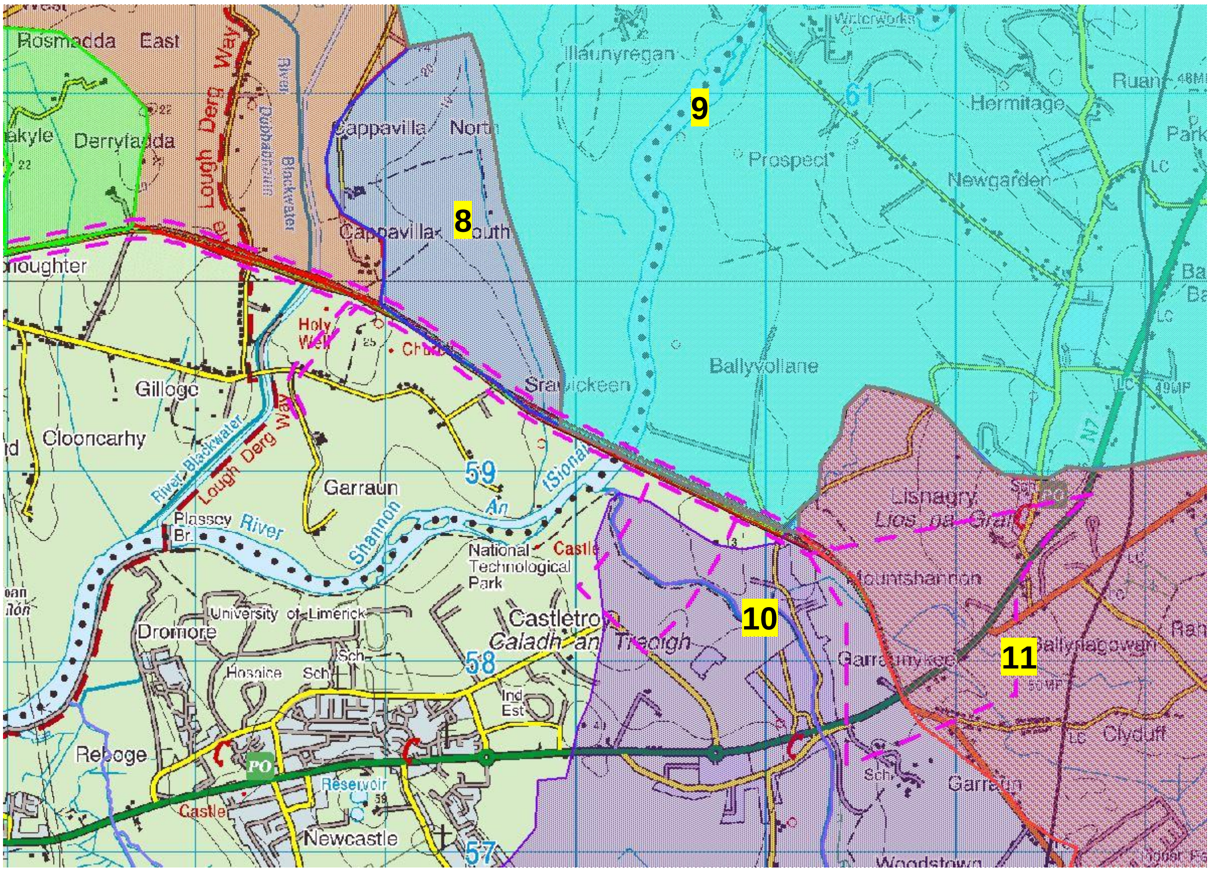

Figure 2.3 Catchment Map (Part 2) showing River Shannon and River catchments at proposed LNDR corridor

6. FLOOD RISK ASSESSMENT OF PROPOSED CORRIDOR AS RELATES TO PROPOSED AMENDMENT

6.1 Existing Flood Risk Mapping

Preliminary flood risk maps for the Limerick City environs are available from the OPW pFRA mapping produced as part of the initial CFRAM Nationwide study and preliminary flood risk mapping of fluvial and coastal sources prepared by JBA for Planning Authorities. These studies are preliminary using DTM lidar datasets and represent screening information of appropriate quality for input to a Strategic Flood Risk Assessment Study.

Currently detailed flood risk mapping for identified vulnerable urban areas has been prepared by the OPW through various CFRAM studies, including the Shannon CFRAM which is relevant to this study (final versions published July 2016). At this stage of the CFRAM process all the identified flood risk study areas have final draft flood inundation mapping prepared and published on the OPW CFRAM website and also Final DRAFT Flood Risk Management Plans.

Final Draft CFRAM flood mapping is available for the proposed River Shannon crossing point, and the Mulkear River Crossing Point (June 2016) refer to Shannon CFRAM drawing S2526LiIK_EXFCD_F1_07 and S2526SPD_EXFCD_F1_03 (published June 2016). Extracts from this mapping is presented in Figure 4.1 to 4.3. This mapping gives an estimated 100year and 1000year present day (i.e. without climate change) flood level for a model node located 450m upstream of the Shannon route corridor crossing location of 9.52m OD Malin and 10.13m OD Malin respectively.

The CFRAM maps presented for the Mulkear River and proposed crossing location to join the R445 Road at Castletroy are presented in Figure 4.2 and 4.3 and show extensive flooding on both sides of the Floodplain. The predicted CFRAM flood levels in the vicinity of the envisaged link corridor crossing at Castletroy are 9.53m O.D. for the 100year Flood Event and 10.13mOD for the 1000year event. The CFRAM mapping indicates a bund protection Flood Defence along the south-east Shannon bank and southwest Mulkear bank.

Earlier sources of flood map information which includes the JBA flood mapping presented in Figures 6.1 and 6.2, shows extensive flooding of the River Shannon Floodplain near Castletroy and extensive flooding of the Mulkear at Annacotty and flooding at Mountshannon Road and along the Thornfield Stream.

Floodmaps.ie is another source of flood information whereby information on historical flooding is presented. The largest recorded flood post the Ardnacrusha scheme on the River Shannon occurred in Nov 2009 followed by the recent and more prolonged flooding in December 2015 and January 2016. Previous large floods were December 2006, December 1999, February 1990 and December 1954.

A preliminary options assessment for the River Shannon Catchment unit 25/26 which includes Limerick City and within the Limerick City AFA the Mountshannon and Annacotty flood risk Area has been completed (July 2016). The recommended measures to protect the Mountshannon and Annacotty Area involve Flood Defences of flood walls and embankments. A Copy of the recommended flood defence measures for the Route Corridor area is presented in Figure 5. These flood defences are designed to protect the various existing at-risk residential and commercial buildings and road access from flooding by the River Shannon, River Mulkear and the Thornfield Stream. The CFRAM Study in the Mountshannon and Annacotty area identified 6 residential dwellings and 2 commercial buildings at risk of flooding from the 100year flood and a further 8 residential dwellings and 2 commercial buildings at risk of flooding from the 1000year Flood Event. The design standard for protection of this area is a 0.1% standard of protection (1000year flood). The proposed walls and Embankments will have additional standard practice freeboards of 0.21m for walls and 0.4m for embankments.

In addition to the Flood defences it is also proposed to replace the under-capacity Thornfield stream culvert under the Mountshannon Road with a larger 2m diameter culvert.

Photo 1 November 2009 flooding in the River Shannon in the vicinity of the proposed LNDR Shannon Corridor

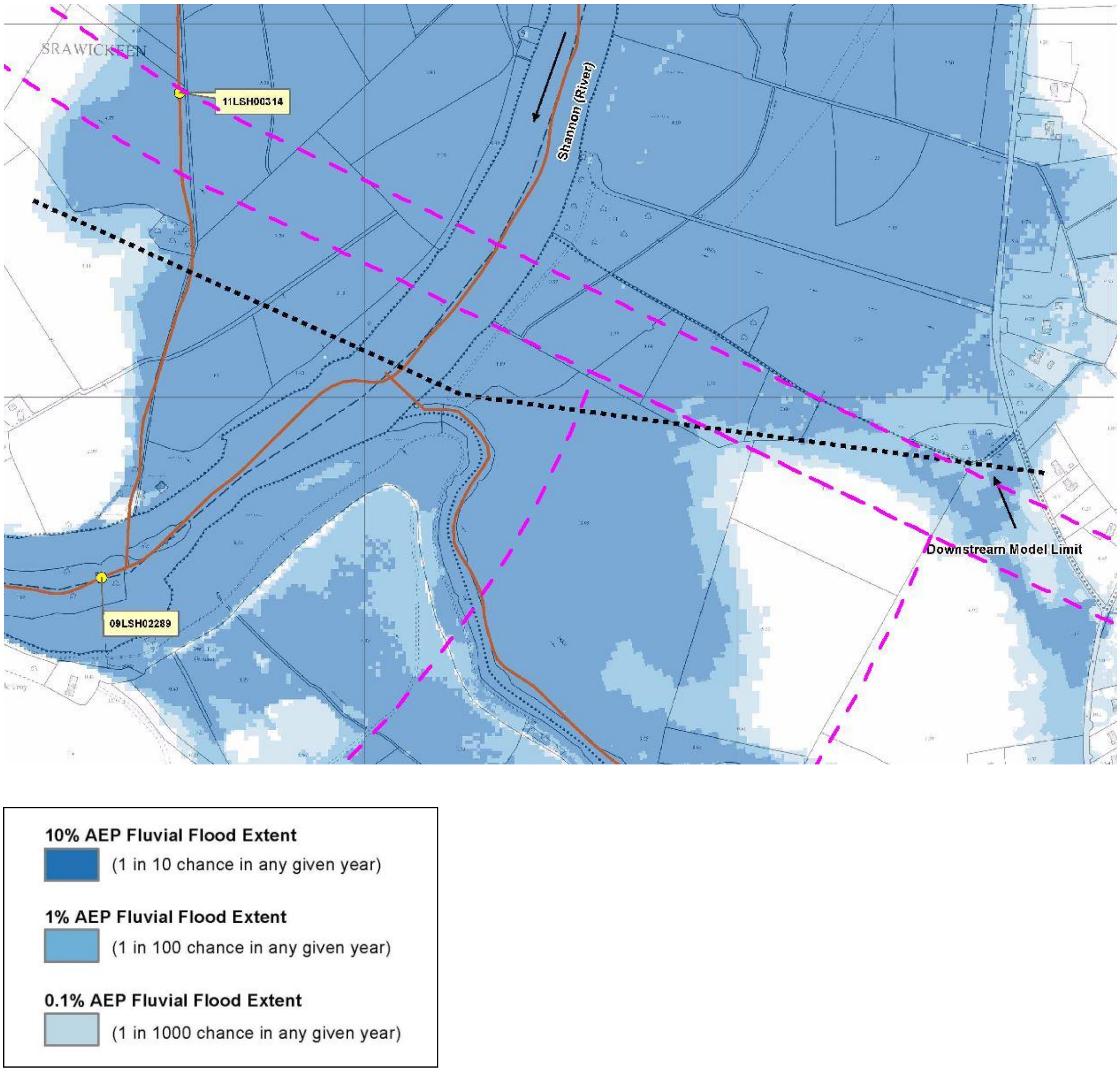

Figure 4.1 Draft CFRAM River Shannon Flood Mapping (Extract from OPW CFRAM S2526SPD_EXFCD_F1_07 drawing)

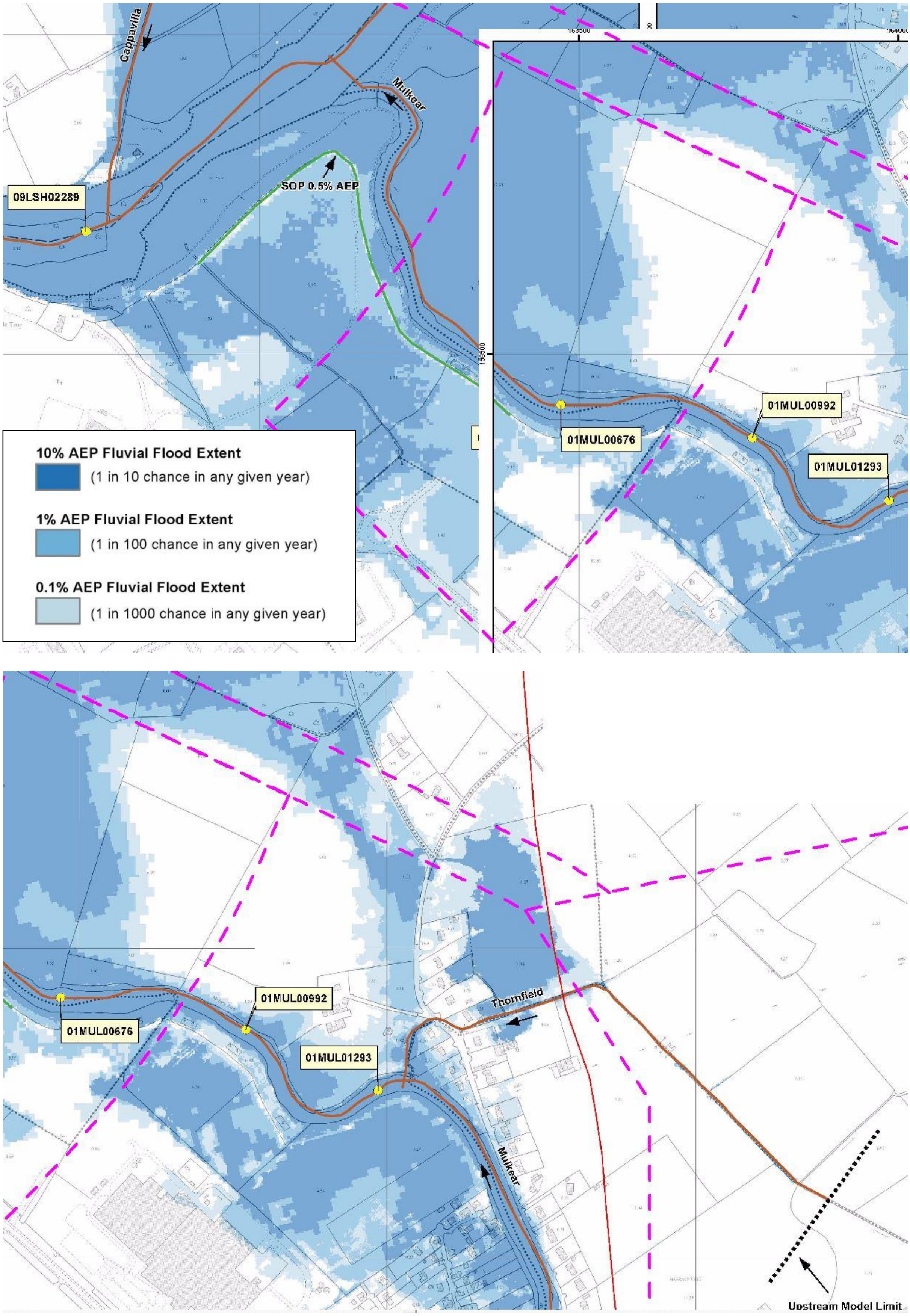

Figure 4.2 Final Draft CFRAM (June 2016) Flood extent Mapping Shannon, Mulkear River and Thornfield Stream (Extract from OPW CFRAM Drawings S2526LIK_EXFCD_F1_03 and S2526LIK_EXFCD_F1_04)

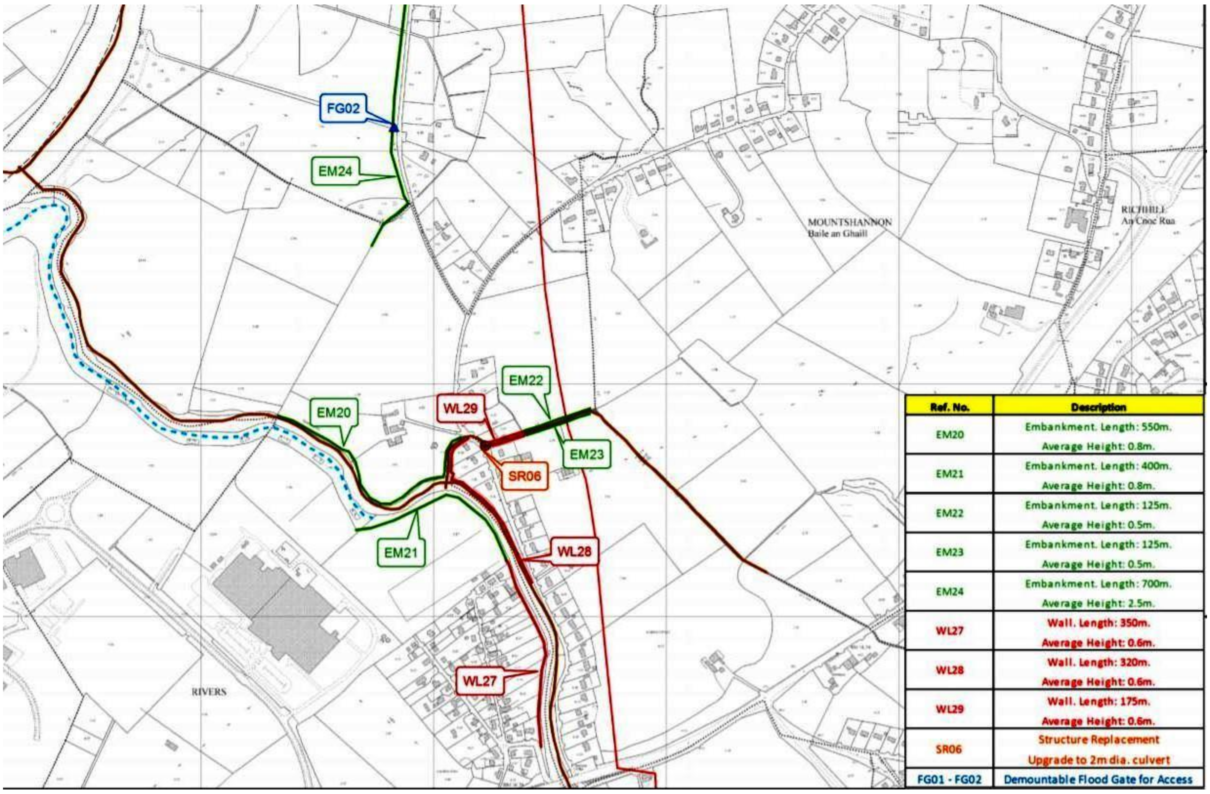

Figure 5 Proposed Flood defence measures for Annacotty – extract from the CFRAM preliminary options report (July 2016)

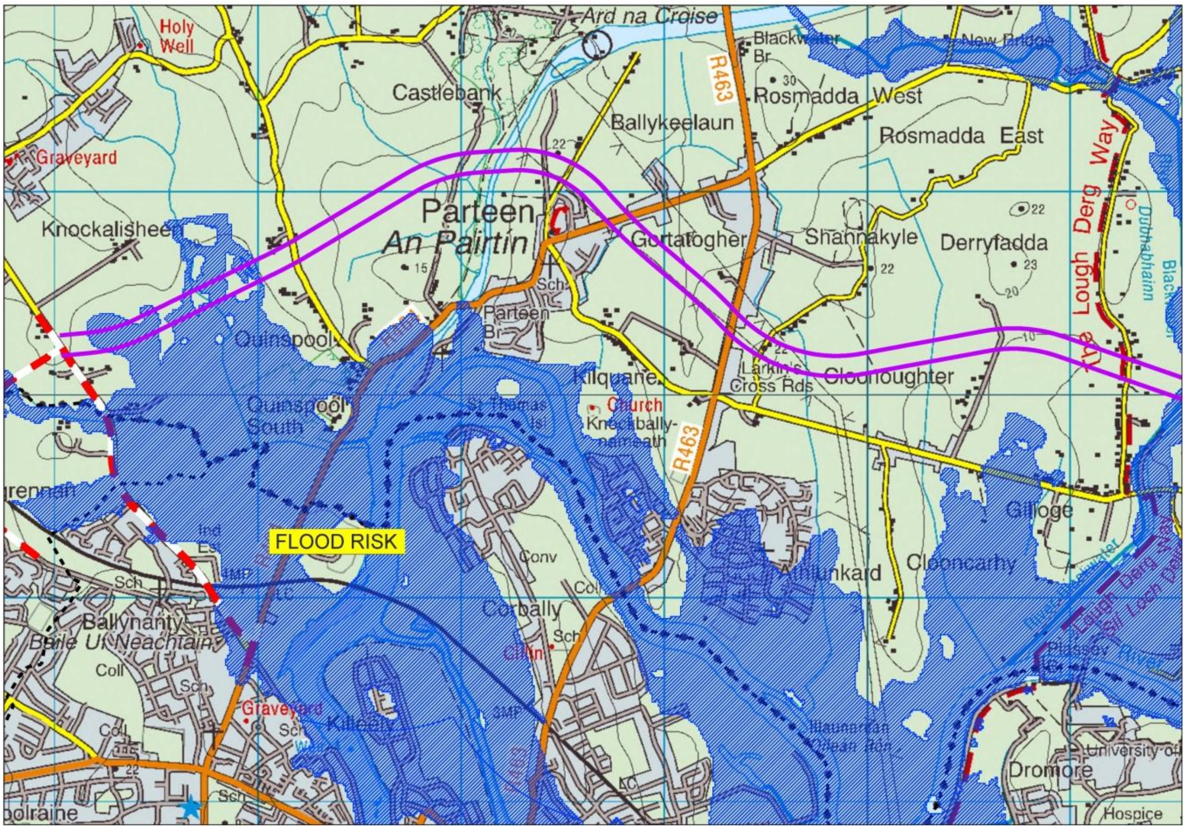

Figure 6.1 Proposed Road Corridor overlaid onto Strategic flood risk mapping for Planning Authorities prepared by JBA (Map 1 of 2)

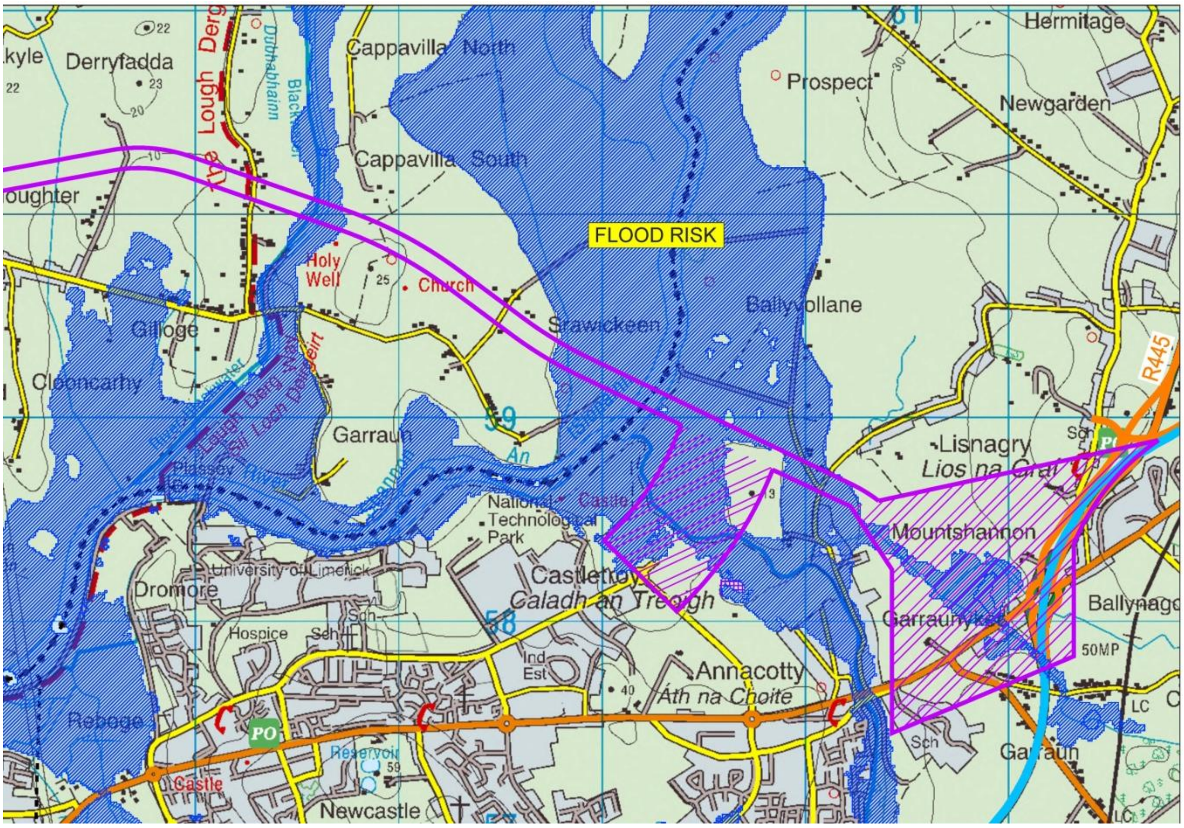

Figure 6.2 Proposed Road Corridor overlaid onto Strategic flood risk mapping for Planning Authorities prepared by JBA (Map 2 of 2)

6.2 Flood Risk Assessment of proposed LNDR Corridor

The Strategic Flood Risk Assessment for the proposed road corridor, in the context of the proposed Variation 5(a) to the Limerick County Plan identifies the following key sources of flood risk that are to be crossed by the proposed LNDR Corridor:

- The River Shannon Crossing and Floodplain,
- The River Mulkear Crossing at Castletroy
- Flooding at Mountshannon by combined sources from the River Shannon, Mulkear River and the minor Thornfield Stream

6.3 River Shannon Crossing

The proposed road crossing point of the River Shannon upstream of the Mulkear Confluence represents an extensive floodplain width of over 1300m at the 100year flood contour, refer to CFRAM figures presented in Figure 4.1 and 4.2. For the existing River Shannon, the estimated 100year flood level from CFRAM (with Ardnacrusha online and diverting flow) is 9.52m O.D. Malin and the 1000year is 10.13m OD. These flood levels result in extensive flooding of the Mountshannon and Ballyvollane areas.

A statistical analysis of 84years of ESB gauged flood flow data for the River Shannon at Parteen Weir was carried out to estimate return period flood flows. The annual maximum series included both the 2009 flood and the recent January 2016 flood. A statistical analysis fitting an EV1 statistical distribution to the Annual Maximum series produced the following total River Shannon flow estimates upstream of Parteen Weir at the head of the Ardnacrusha Head Race (Q10 of 677cumec, Q100 of 877cumec and Q1000 of 1074cumec). The total capacity of the Ardnacrusha Headrace and hydropower facility is c. 400cumec which represents almost a 50% diversion of the 100year flood flow rate. However, during the larger flows this diverted flow rate cannot be achieved due to the drawdown effects by the River Shannon flow over the Parteen Weir which draws down the upstream levels at the entrance to Ardnacrusha Head Race and thus the head available for flow. A review of the flow data through Ardnacrusha suggests that during large flood events the maximum flow rate through Ardnacrusha is approximately 360cumec. Using this figure as the diverted flow the estimated peak flow in the River Shannon downstream of Parteen Weir is a Q10 of 315cumec, Q100 of 517cumec and a Q1000 of 714cumec. These flows reasonably agree with the final Draft CFRAM Study estimates of a 10year at 330cumec, the 100year at 524cumec and a 1000year at 714cumec. For conservative purposes the slightly higher CFRAM design flow estimates will be used.

Given the high flood risk associated with this crossing a detailed flood modelling assessment using a full 2-dimensional hydraulic model of the River Shannon and River Mulkear river channels and floodplain area in the vicinity of the proposed corridor crossing was carried out to assess the flood risk, quantify the flood extents and understand the dynamics of flooding in this sensitive area along the proposed corridor. TELEMAC hydraulic modelling software was used to model the complex two-dimensional flow field associated with the River Shannon and River Mulkear confluence and floodplain lands in the vicinity of Ballyvollane, Castletroy and Mountshannon. TELEMAC is the industry standard software for hydraulic modelling of 2-dimensional and 3-dimensional flow fields and ideally suited to this application as it is set up with a variable grid that can refine and expand as required to suitably define the channel, embankment and floodplain geometry.

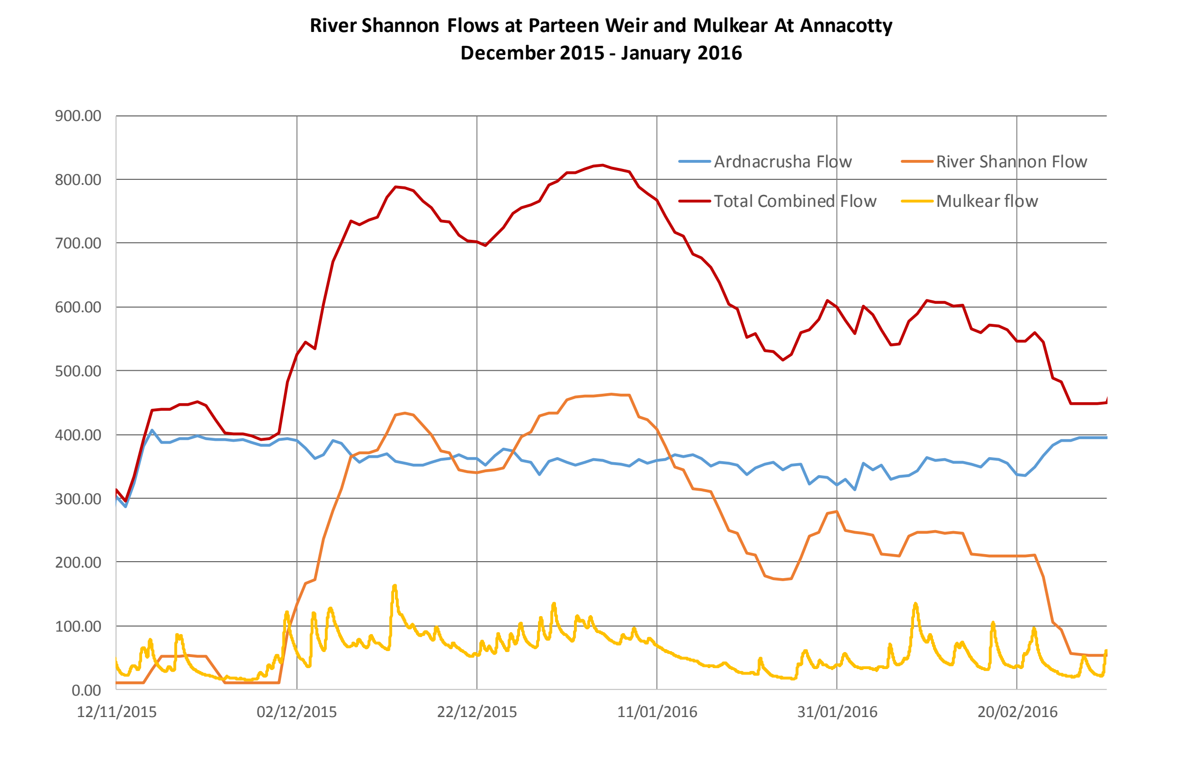

Figure 8 Gauged Flood Flows in the Shannon at Parteen Weir and the Mulkear River at Annacotty for the December 2015-Jan 2016

The data used in this model was river section survey data from the OPW CFRAM Project (2013 – Survey), OPW Lidar Dataset at 2m grids (2012) survey also from the CFRAM project, route corridor topographical and high resolution lidar survey (2014) and a recent (Feb 2017) topographical survey of the IDA Flood Embankment at Castletroy. This flood embankment at Castletroy was surveyed to assess the level of protection it provides to IDA owned development lands at Castletroy. The survey covered 1450m of embankment length and is presented below as a longitudinal top of bank profile from downstream at the Northwest end of the IDA Site adjacent to the River Shannon to upstream along the Mulkear to the Southeast end of the site, refer to Figure 9. The top of bank levels undulate and typically provides a protection level of 9.7 to 10.4m OD from the River Shannon to the River Mulkear ends, refer to Figure 9.

This Flood embankment will prevent the conveying flood waters from both the Shannon and the Mulkear entering these protected lands at the 100year flood flows. At the 1000year event out-of-bank flows are likely to enter from upstream via the Mulkear Floodplain (Left) southwest bank and downstream from the River Shannon and also slight overtopping at some low sections of flood embankment along its length. During floods local drainage and groundwater on the IDA protected lands can build-up behind the defences and given the prolonged nature of flooding in the Shannon (many days) the local drainage waters are likely to reach or slightly surpass the Shannon flood levels. It is not clear whether the drainage channel outlet from these lands to the Shannon at the downstream end is flapped. If un-flapped or in poor condition the River Shannon will flood these lands to similar levels as the Shannon.

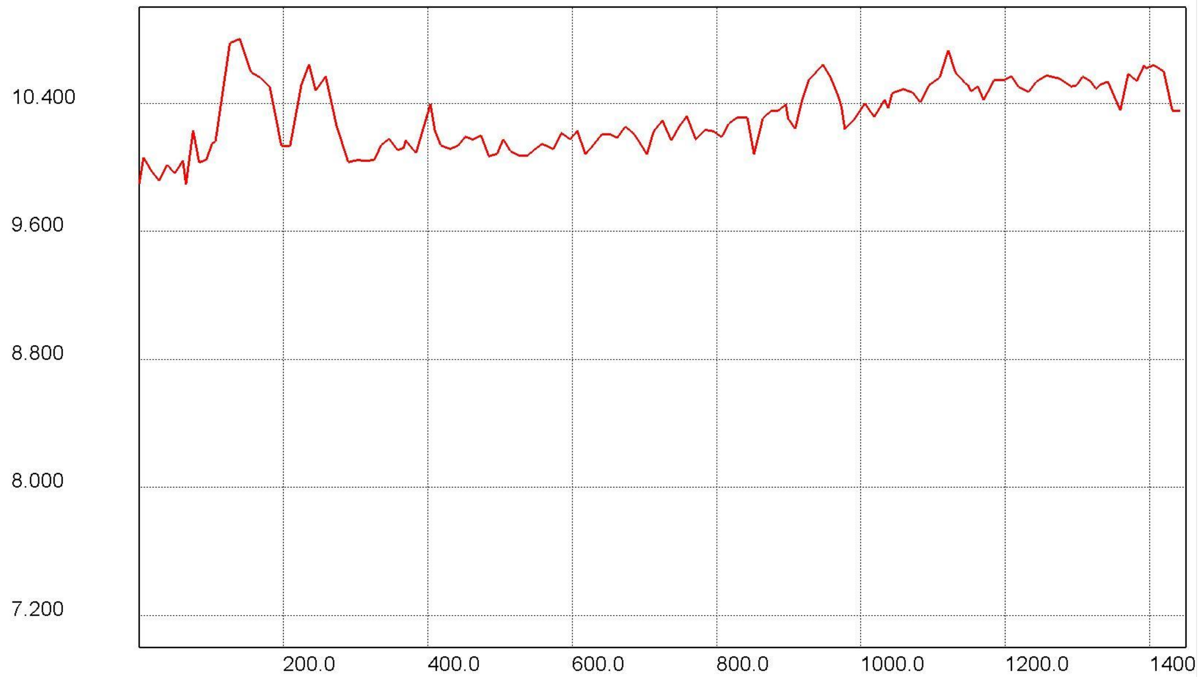

Figure 9 Longitudinal profile of IDA Flood Embankment top of bank level a long Shannon and Mulkear.

Flood Modelling

Flood simulations were conducted for River Shannon modelling 100year and 1000year flood flows based on the CFRAM estimates as follows:

The 100year River Shannon Flood Event is

1. An upstream River Shannon Flow rate of 524cumec combined with a Mulkear Flood flow of 116cumec to produce a downstream River Shannon 100year Flood Flow magnitude of 640cumec,

and for the 1000year River Shannon Flood Event

2. An upstream River Shannon Flow rate of 714cumec combined with a Mulkear Flood flow of 142cumec to produce a downstream River Shannon 1000year Flood Flow magnitude of 856cumec.

The flood extents for these simulations (1 and 2) are presented in Figure 10. The predicted flood levels at the CFRAM node (11LSH00708) located 450m upstream of the Bridge Corridor crossing of the Shannon and node (09LSH02289) located 600m downstream of the Bridge Corridor and 400m downstream of the Mulkear confluence are presented below and show reasonable agreement between the LNDR model and the CFRAM model predictions.

	100year Flood Level mOD		1000year Flood level mOD	
Node Reference	CFRAM model Study	LNDR 2d model	CFRAM model Study	LNDR 2d model
11LSH00708	9.52	9.51	10.13	10.16
09LSH02289	9.12	9.09	9.70	9.73
Shannon Bridge Corridor		9.50		10.14

Velocity vector plots at the peak 100year and 1000years flows are presented in Figures 11 and 12 which illustrate the 2-dimensional flood flow pattern and potential flow paths.

The 2-dimensional simulations show that the predicted flood characteristics of this section of the River Shannon at the main LNDR crossing have a very gentle hydraulic gradient (almost lake like conditions) giving rise to large flood flow depths both in the river channel and in the extensive flood plain area on both sides of the river, resulting in low channel velocity magnitudes. Such hydrodynamic conditions lessen the potential impact of floodplain encroachment by a road development on flood conveyance because of the low velocities and correspondingly low energy loss as a result of floodplain contraction.

It should be noted that the River Shannon downstream reach 400m below the Mulkear confluence narrows significantly. This channel section has over time and through maintenance neglect become partially infilled and obstructed by sediment with Islands formed within the channel and mature woodland vegetation growing along the river banks and on these islands representing a very restricted channel. The modelling predicts a fall in flood level of 1.8m in approximately 1400m (0.13% gradient), whereas, upstream in the wide floodplain reach section the flood levels fall by approximately 0.1m in 1800m (0.0055% gradient), which is more akin to standing water conditions of a lake. The velocity plots show significantly higher channel velocities in the downstream confined section of the river. This section retards flood flows and is the possible cause of the extensive upstream flooding.

In terms of flood risk and potential impact of the Corridor Simulations 1 and 2 are the critical design conditions for upstream of the LNDR River Shannon Crossing, whereas, simulations 3 and 4 presented for the Mulkear below in sub-section 6.2.3 are the critical design conditions for assessing potential impacts on the Mulkear River and Floodplain area as a result of the LNDR corridor crossing at Mountshannon and the proposed link to the R445 at Castletroy.

Flood simulations using the LNDR Model of the River Shannon Crossing were carried out to assess the minimum bridge opening width necessary to span the channel and floodplain area at the proposed corridor crossing location. The conclusion reached is that for the main Shannon channel crossing a minimum span width of 300 to 400m is sufficient to mitigate significant impact on upstream flood levels and flood risk to properties.

The loss of floodplain storage by the proposed long road embankments through both the Shannon and Mulkear floodplains was assessed and the flood impact was found not to be very sensitive to the loss of flood storage. The reasons for this are due to the prolonged nature of flooding, the large catchments involved and the very extensive floodplain area locally and in the upstream catchments and lakes.

It is recommended that the proposed minimum soffit level for the proposed bridge be set sufficiently high as to achieve a minimum freeboard clearance of 1m above the 100year flood flow with a climate change factor of 20% (equivalent to the 1000year) and with all flood flow passing down the River Shannon, i.e. without the assistance of the Ardnacrusha Diversion channel. Based on these levels and allowing for minimal clearance for debris to pass underneath the bridge a minimum soffit level has been determined for the bridge at 12mO.D. However, a higher soffit level is likely to be required for environmental (shading etc.), navigation and amenity purposes.

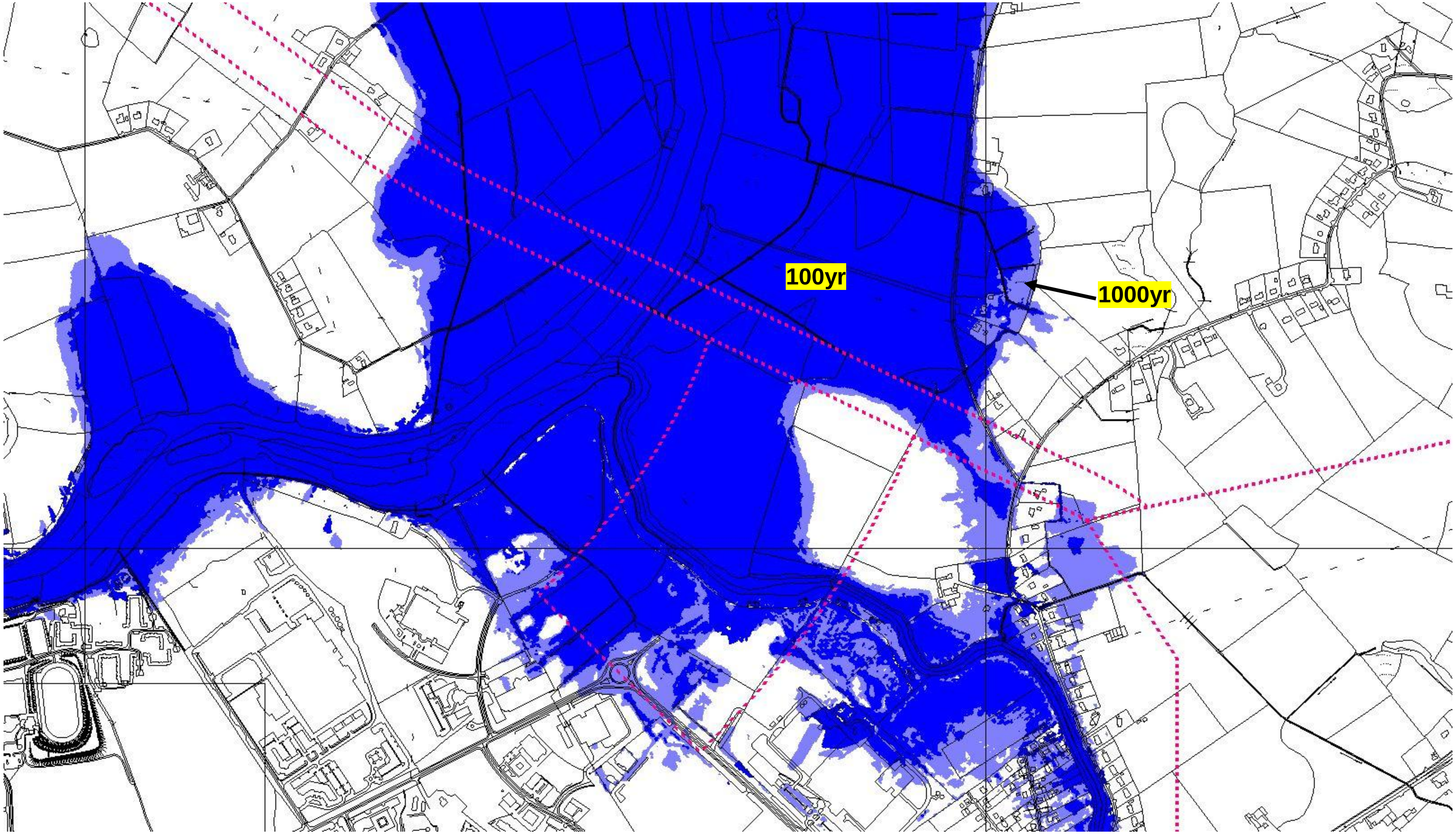

Figure 10 River Shannon 100year and 1000year year Flood Levels (Simulations 1 and 2)

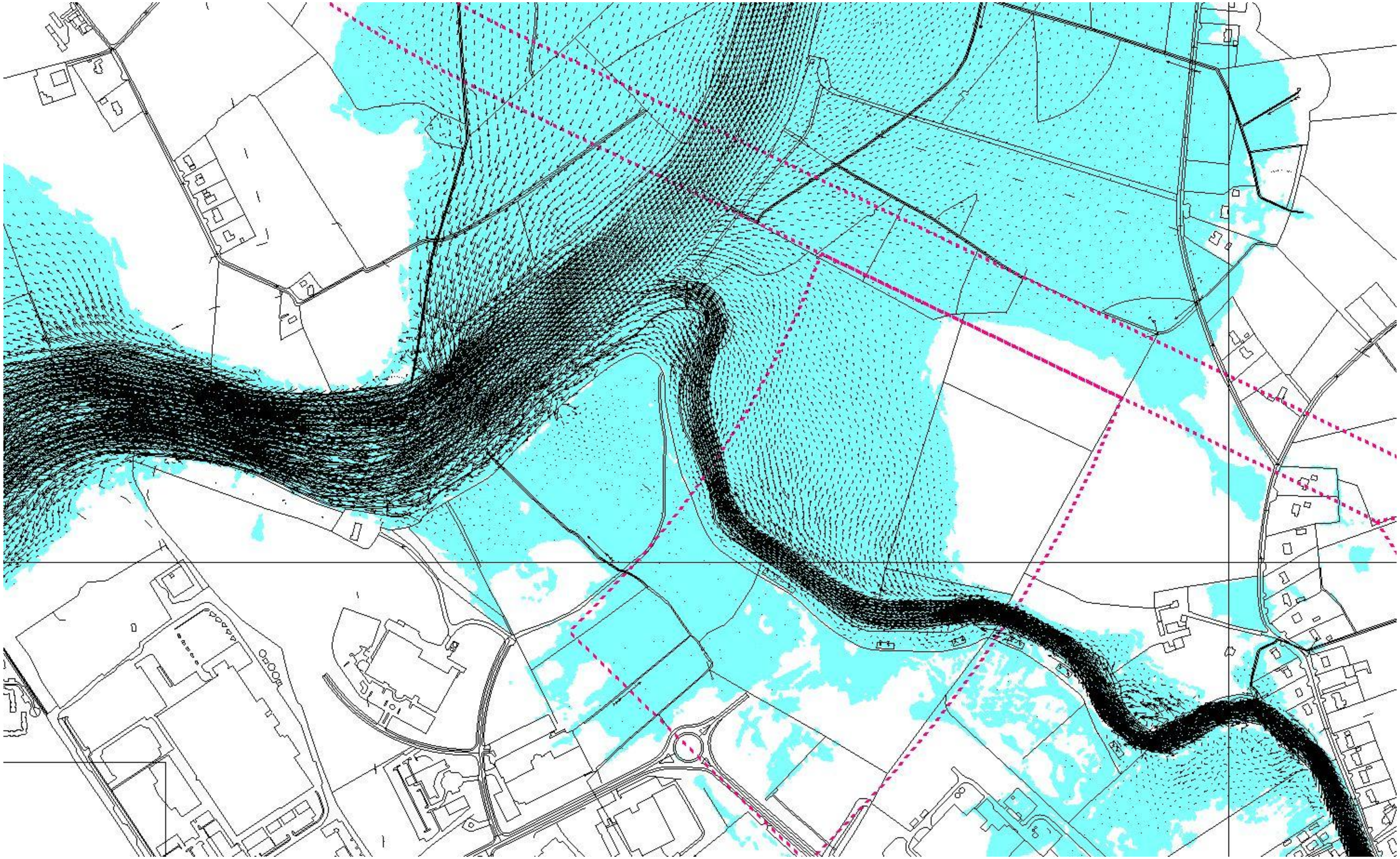

Figure 11 Computed Velocity Vector Plot at 100year Shannon flood Peak (Simulation 1)

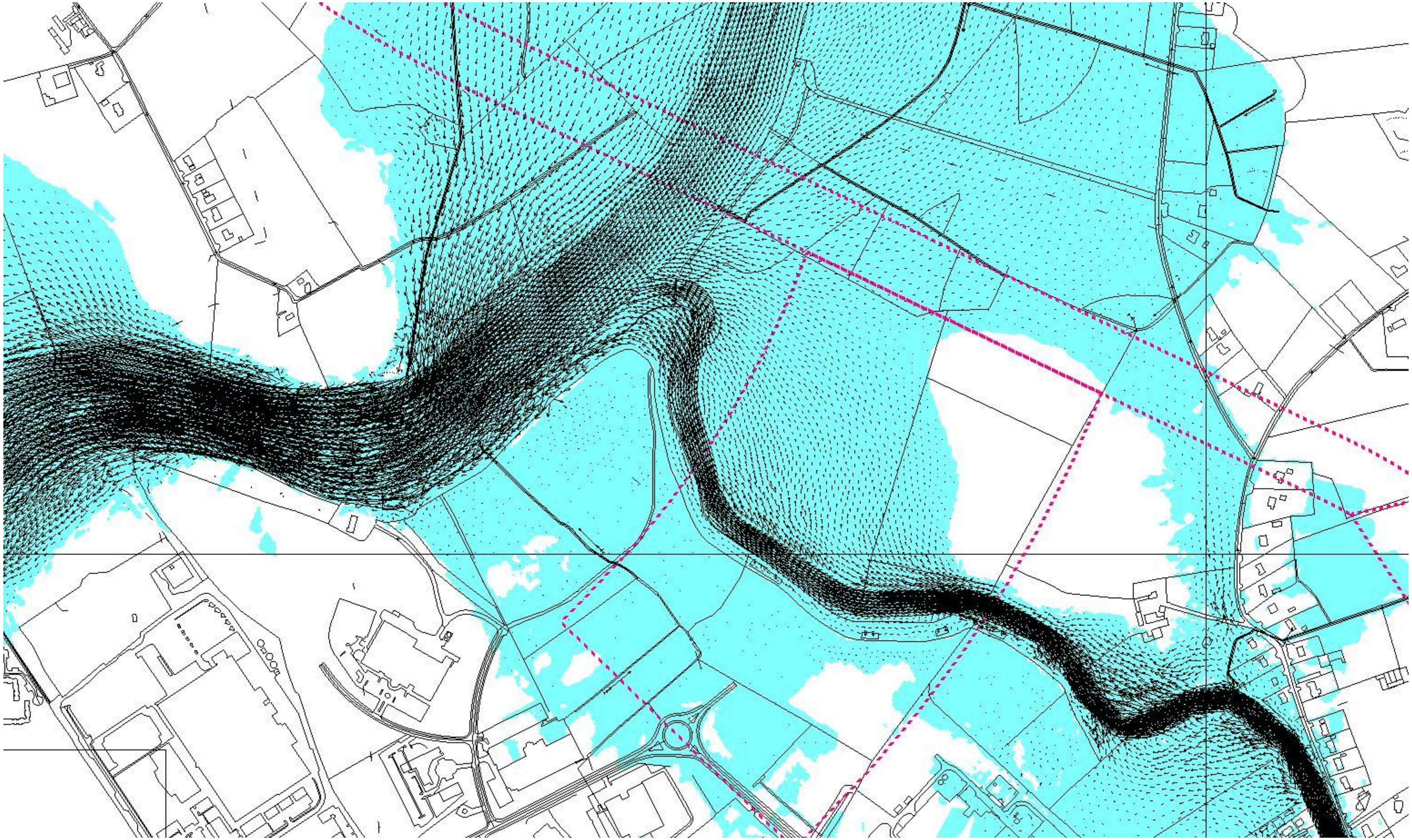

Figure 12 Computed Velocity Vector Plot at 1000year Shannon flood Peak (Simulation 1)

6.4 River Mulkear Crossing

The Mulkear River which is a smaller, flashier river joins the Shannon a short distance downstream of the proposed road corridor. This has a catchment area of 656km^2, whereas the Shannon has an upstream catchment area of 10,855km^2 and therefore the Mulkear only represents just over 6% of the Shannon to the LNDR corridor. The hydrograph for the December-January 2016 flood event presented earlier in Figure 8 shows the flashy nature of the Mulkear relative to the Shannon with multiple shorter duration peaks (1 to 2day peaks), whereas the Shannon peak flow is prolonged over many days. The Mulkear at c. 6% of the Catchment area provides the equivalent of c. 20% of the River Shannon peak flood flow over Parteen weir. The CFRAM study suggests that the combined River Shannon flood event has a contribution from the River Mulkear of 106cumec at 10year, 116cumec at the 100year and 142cumec at the 1000year. The CFRAM study also estimates 10, and 1000year flood flows in the Mulkear to Annacotty of 161.8cumec, 199.7cumec and 237.6cumec. The FSU flood flow estimation method was applied to the Mulkear using the Annacotty gauge as a pivotal site to set the median flood flow to an actual reliable gauged value and derive the flood growth curve from a pooling group of hydrologically similar gauged catchments. This method produced 100year and 1000year flood flow estimates of 235cumec and 290cumec which are almost 20% higher than the CFRAM estimates and used in this assessment.

Flood Modelling

A second series of return period flood flow simulations was carried out with emphasis on impact of peak flow rates in the Mulkear River using the FSU Flood Estimation Method giving a peak flow rate of 235cumec and 290cumec for the 100year and 1000year return period probabilities respectively. These Mulkear return period peak flow rates were combined with large River Shannon flow rates of 405cumec and 556cumec, so that overall the 100year and 1000year Shannon flood flow magnitudes downstream of the Mulkear confluence are achieved (640cumec and 856cumec respectively). The simulations are as follows:

3. An upstream River Shannon Flow rate of 405cumec combined with a Mulkear Flood flow of 235cumec to produce a downstream River Shannon 100year Flood Flow magnitude of 640cumec,

4. An upstream River Shannon Flow rate of 556cumec combined with a Mulkear Flood flow of 290cumec to produce a downstream River Shannon 1000year Flood Flow magnitude of 846cumec,

Simulations 3 and 4 for the Mulkear are significantly more onerous in terms of flooding than the CFRAM assessment and are expected to represent a conservative worst case scenario. The predicted flood levels from these simulations in the vicinity of the Castletroy Link Corridor Crossing are 9.66mOD and 10.2m OD and 9.74 and 10.23m OD at the LNDR Corridor crossing near the Mountshannon Road for the 100year and 1000year Flood Events.

As can be seen from Figure 13 extensive flooding of the Mountshannon area, the floodplain at the Link Corridor and also the IDA protected lands is predicted under the existing case. The IDA protected lands are shown to be flooded by the Shannon backing up from downstream at the 100year flood conditions and combined flooding by some over-topping of the Mulkear River on its left (southwest) bank and backing up from downstream by the River Shannon at the 1000year Flood Event. The flood velocity plots presented in Figures 14 and 15 show the various routes of out-of-bank flooding and importantly show backing up of the Thornfield stream locally at Mountshannon Road and the flooding of a low-lying area to the north of the Thornfield Stream and to the east of the Mountshannon Road at the rear of a number of large houses.

The simulations also show that the Mulkear River, which is channelized upstream through Annacotty, relies significantly on its right overbank downstream at the proposed crossing to convey flood waters to the Shannon, particularly as the Left floodplain is cut off by the IDA flood embankments. The simulations particularly for the 100 and 1000year Mulkear design flows show the existence of a northerly flood path, parallel to the Mountshannon Road for some out of bank floodwaters from the Mulkear to make their way to the River Shannon northwards. The proposed LNDR corridor crosses this northerly flow path and therefore to avoid significant flood impact locally this flow path needs to be maintained by providing a Bridge Structure to span this section of floodplain and avoid cutting it off.

The proposed Link Road Connection will require significant spanning of the right bank floodplain of the Mulkear River to minimise upstream flood impact. A total span width ranging between 200m to 300m of the main channel and right bank would sufficiently reduce impact on upstream flood levels and flood risk to the Annacotty and the Mountshannon area.

The lands on the left bank protected by the IDA flood embankment do not have an important flood conveyance function but do have a local flood storage function and therefore a road embankment through these lands will reduce the available flood storage for local drainage and overtopping events resulting in a potential increase in flood levels and flood risk. Some compensation storage or spanning of the flood protected lands may be required to avoid local flood impacts.

It is recommended that the proposed minimum soffit level for the proposed Mulkear bridge is set sufficiently high as to achieve a minimum freeboard clearance of 1m above the 100year flood flow with a climate change factor of 20% (equivalent to the 1000year) and with all flood flow passing down the River Shannon, i.e. without the assistance of the Ardnacrusha Diversion channel. Based on these levels and allowing for minimal clearance for debris to pass underneath the bridge a minimum soffit level has been determined for the bridge at 12mO.D. However, a higher soffit level is likely to be required for environmental (shading etc.), navigation and amenity purposes.

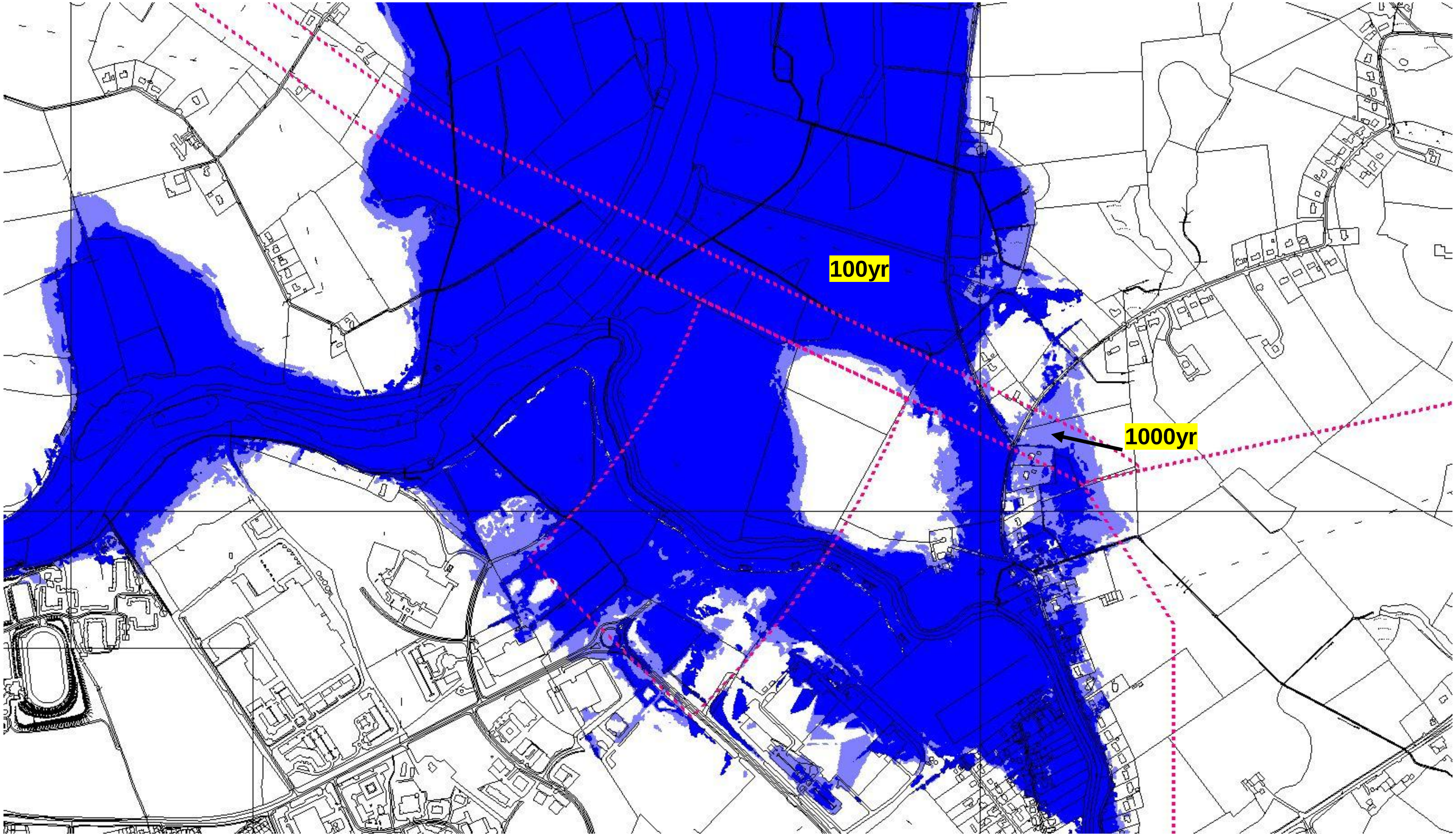

Figure 12 Mulkear and Shannon 100year and 1000year year Flood Levels (Simulations 3 and 4)

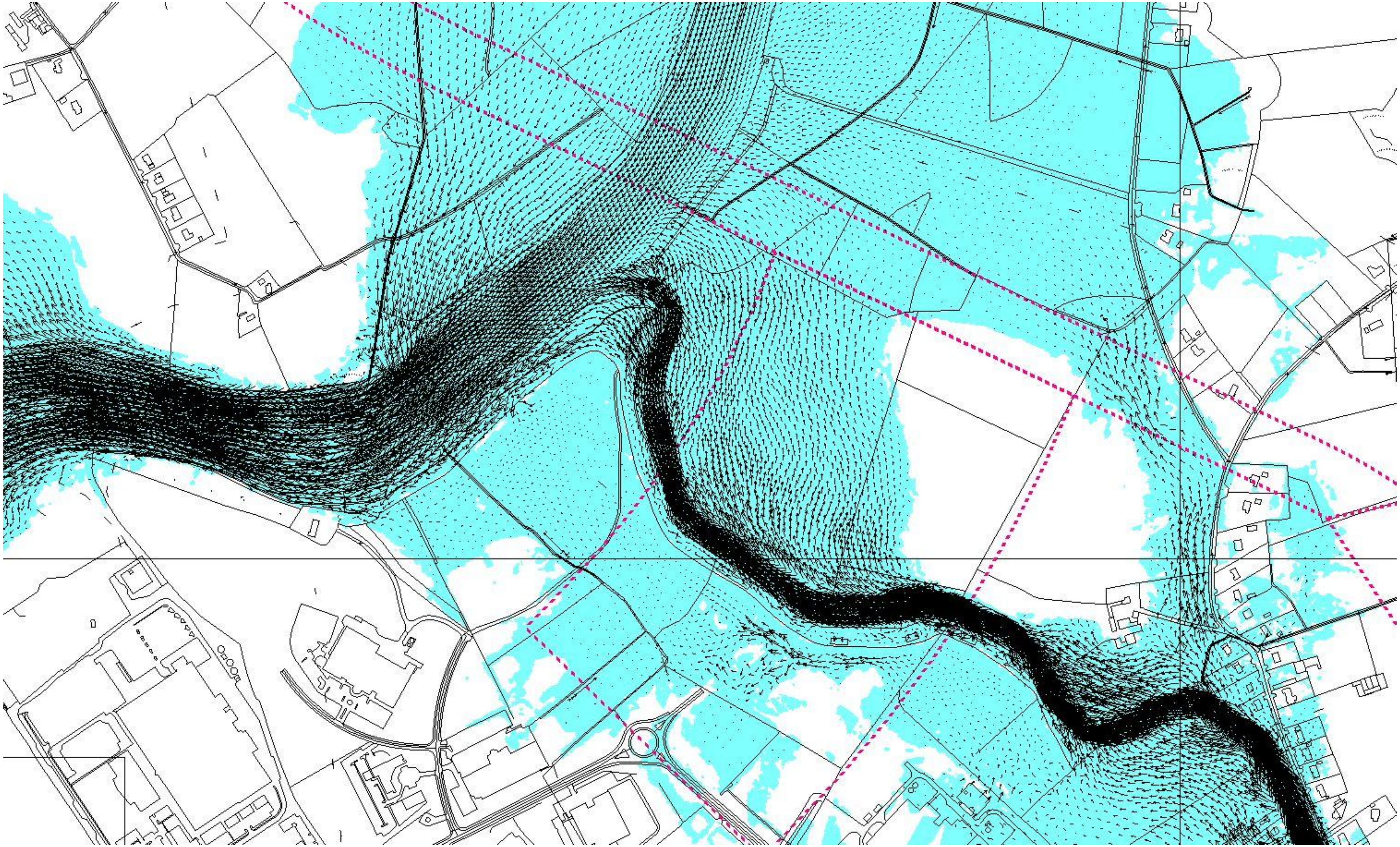

Figure 13 Computed Velocity Vector Plot at 100year Mulkear and Shannon flood Peak (Simulation 3)

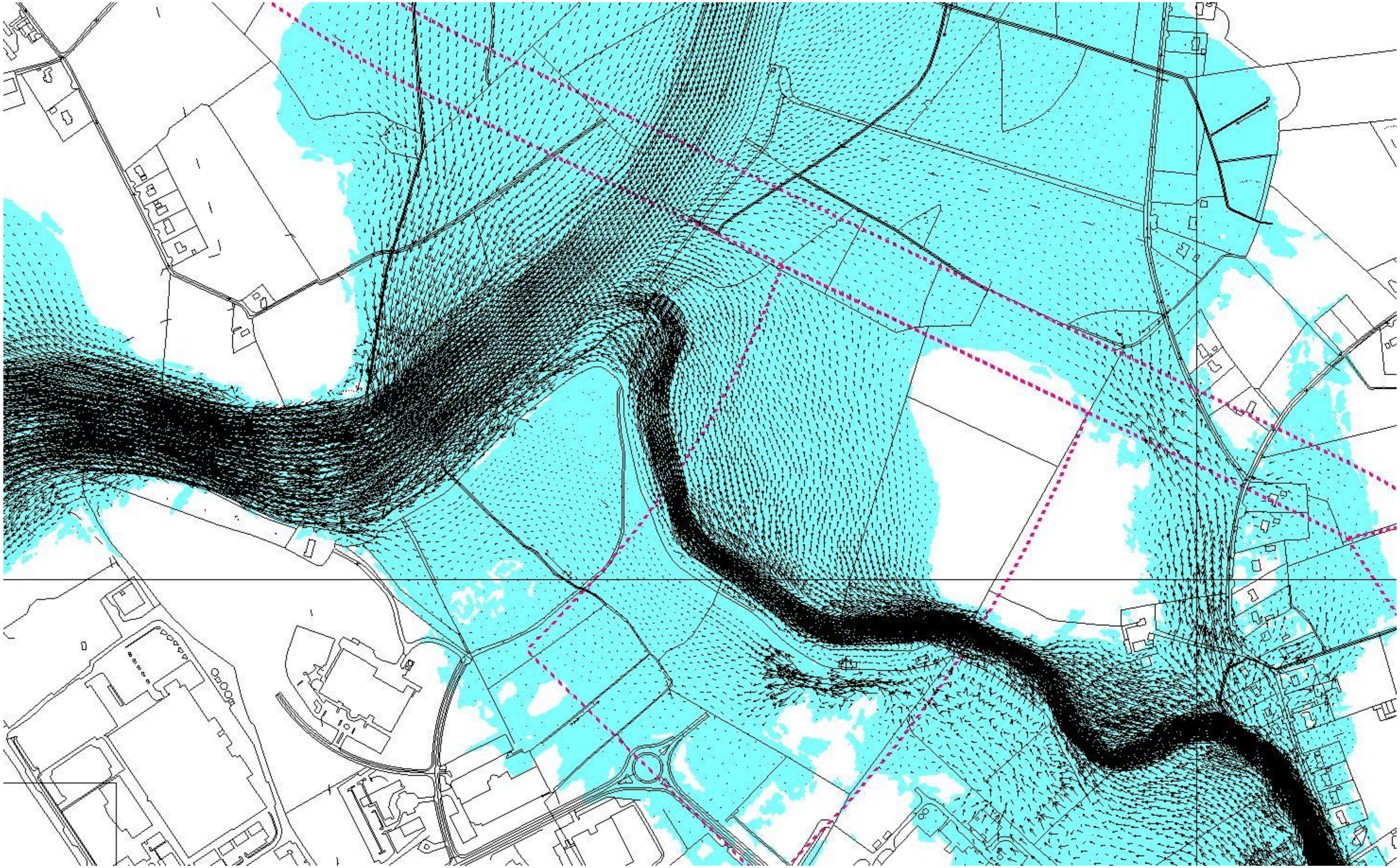

Figure 14 Computed Velocity Vector Plot at 1000year Mulkear and Shannon flood Peak (Simulation 4)

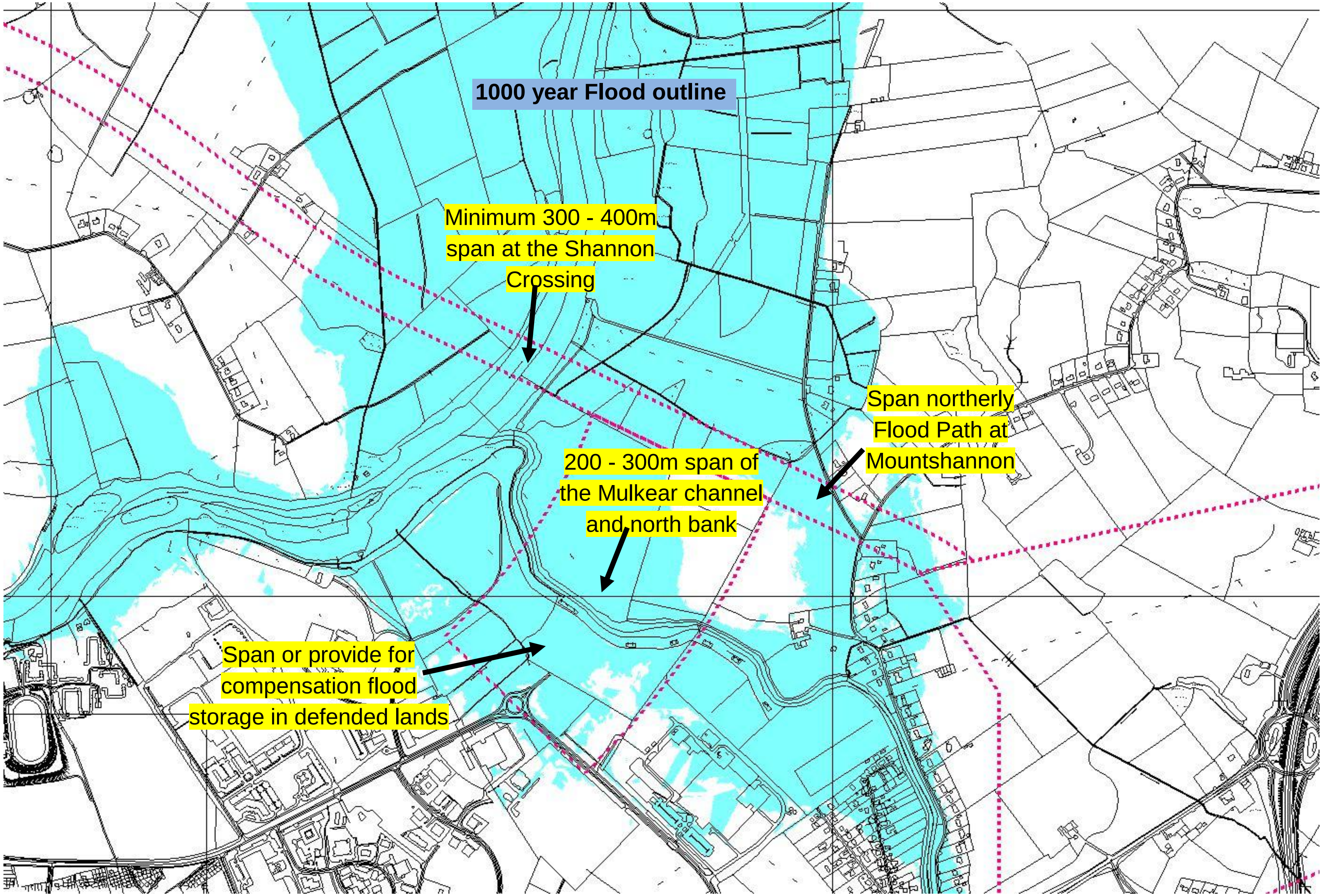

Figure 15 Minimum Flood Requirements at Corridor Crossing of Shannon and Mulkear

6.5 Thornfield Stream Mountshannon

The proposed road corridor crosses the Thornfield Stream to the northeast of Annacotty. This is a minor stream that flows under the Mountshannon Road at Annacotty and joins the Mulkear River. The catchment area is 5.4km^2 and has an estimated 100year flood flow rate for this stream of 2.36cumec and 3.11cumec at the 1000year. At the proposed corridor crossing the JBA flood risk mapping indicates a potential for out of bank flooding. The final draft CFRAM mapping for this stream does not show any out of bank flooding from the Thornfield Stream at the proposed corridor location. Flooding is identified downstream as a result of the backing up of floodwaters from the Mulkear and Shannon Rivers, Refer to CFRAM mapping presented in Figure 4.2 and Figures 9 and 12.

A 1-Dimensional HEC-RAS model of this stream was developed using the CFRAM River Sections. The above return period flow rates for this stream were simulated and found that the extent of out of bank flooding area within the corridor is minor and confined close to the river channel due to a steep flow gradient of typically 1 in 160.

The assessment indicates that the various field and road crossings are generally undersized for the 100 and 1000year flood events and overtop with some out of bank occurring locally. In particular, the Mountshannon Road Culvert which is a 0.6m wide by 1m high rectangular culvert that has been piped immediately upstream for c. 45m in a 0.75m diameter concrete pipe which has very limited flow capacity. Simulations show this culvert will easily overtop across the Mountshannon Road and also back-up along its channel with a potential for flood waters to overtop the channel and flow northwards to an existing identified low-lying flood risk area adjacent to the stream (refer to Figure 4.2 and Figures 9 and 12 which show this flood area to the north of the Thornfield stream at Mountshannon.

In order to prevent a worsening of flooding as a result of road scheme, either localised or upstream or downstream, it is recommended that the following mitigation be included at the crossings of the Thornfield Stream

- full storm attenuation be provided for any potential road drainage outfall discharging to this stream,
- channel and overbank conveyance be provided at the crossing point and through the floodplain areas so as not to increase flood levels and flood flows.

6.6 Proposed CFRAM Flood Protection Measures

The proposed CFRAM Flood Protection Measures for the Annacotty-Mountshannon Area are presented in the CFRAM Preliminary Options Report for unit of management 25/26 (July 2016.These have been summarised earlier in this report in Section 6.1 and fig 5.The LNDR will not impact the implementation of these protection measures or reduce the design standard of the proposed protection. Furthermore, the proposed LNDR scheme will not be dependent on the implementation of the Flood Protection Measures to mitigate flood impacts.

The SFRA has assessed the impact of the proposed OPW flood relief scheme on the LNDR corridor and river Crossings. Examination of the Flood Protection Measures proposed in the area of Mountshannon indicates that they will eliminate a northerly flow path for the Mulkear and confine flow to the river channel through Annacotty. An important additional aspect is that the Flood Protection Measures will not increase the flood risk to the LNDR Corridor or the required floodplain spans.

This SFRA has examined the flooding process and assessed the bridge spans required to minimise bridge afflux so not to cause unacceptable adverse flood impacts elsewhere.

7. JUSTIFICATION TEST

Section 3 above outlines the process for assessment of flood risk in accordance with the Planning System and Flood Risk Management Guidelines for Planning Authorities (November 2009) . Section 3.4 of this report refers to Chapter 4 of the Guidelines - Flooding and Spatial Planning - and outlines the Justification Test to be applied for the preparation of development plans. The requirements of Box 4.1 (reproduced as Plate 1 in Section 3.4.5 above) have been applied as follows:

7.1 Plans and Policies

The proposed Limerick Northern Distributor Road (LNDR) represents strategic transport infrastructure for Limerick City and its environs and the provision of such infrastructure forms part of the planned future sustainable development of the region. The proposed Variation is consistent with the published plans and policies as follows:

National Spatial Strategy (NSS)

Limerick-Shannon is seen as an important ‘Gateway’ in the Mid-West with the Limerick Northern Distributor Road supporting each of the following NSS objectives:

- Support the economic growth of National Gateways;
- Promote balanced regional development;
- Achieve a better spread of investment and work opportunities across the country;
- Ensure that growth of towns and cities meets the economic and social needs of an increasing population, while also protecting the environment; and
- Improve quality of life for Irish communities.

Regional Planning Guidelines 2010 - 2022

The Mid-West Regional Authority developed the Regional Planning Guidelines 2010-2022 to set clear objectives and targets in relation to the development plans of the planning authorities and are specific in relation to future population, settlement strategy and development distribution and infrastructure investment priorities.

The Regional Planning Guidelines 2010-2022 identify the provision of the Limerick Northern Distributor Road as a key investment priority required to support the development of the mid west region. The guidelines envisage the Limerick Northern Distributor Road as a crucial element of the strategic development of the Region, linking the M7 and N18 to protect the City Centre, to enhance access to Shannon International Airport and its related industrial zone from eastern parts of the country, and to enhance access to the University of Limerick and its associated knowledge based industrial zone.

Mid West Area Strategic Plan (MWASP)

The Mid-West Area Strategic Plan 2012-2030 (MWASP) examined land-use and transportation issues in the mid west region. Its aims are to

a) Strengthen and enhance the functionality of the Limerick-Shannon Gateway as identified in the National Spatial Strategy 2002-2020;
b) Provide guidelines for the promotion of a more balanced regional settlement pattern through a more structured dispersal of population;
c) Identify Limerick and the Mid-West strategic requirements for the next 30 years;
d) Inform future social, physical, educational and economic infrastructural spending programs;
e) Inform current and future National Development Plans, Regional Planning Guidelines and National Spatial Strategy areas; and
f) Aid in securing National funding.

Key features which have been identified to facilitate a more sustainable form of spatial development in the Limerick Area are:

a) Development that is concentrated rather than dispersed allowing for it to be served more efficiently by public transport;
b) Improved access to locations of employment, education, health, leisure and residence through the provision of a high quality sustainable public transport system; and
c) Develop new residential neighbourhoods and employment zones that can be adequately served by public transport.

By implementing the recommendations outlined in MWASP, the mid west will develop with a strong City at its core which will drive the region’s economy and improve its image. The result shall deliver a better quality of life for its citizens. MWASP notes that the regional and local road networks form a significant part of a regional transport strategy to aid in competitiveness, connectivity and accessibility and identifies the Limerick Northern Distributor Road as one of the most important of these schemes. This scheme, crossing two local authority jurisdictions would enable the region to connect and access the northern periphery of the city limits and protect the City Centre. It also brings the ability to make the regeneration area more accessible, enhance access to Limerick University and the related industrial zones.

Provision of the LNDR has also been included for in the current Clare County Development Plan (2017-2023) and the South Clare Local Area Plan (2012-2018).

7.2 Designation of lands to achieve proper planning and sustainable development

The proposed development of the LNDR addresses the relevant specific requirements of the Guidelines as follows (and using the same numbering system):

(i) The development is essential to facilitate regeneration of the Moyross area and will provide enhanced access to employment and educational opportunities. It also facilitates expansion of Castletroy/University area of Limerick as identified in the assumptions of MWASP.

(ii) The proposed LNDR will be developed, in the main, on under-utilised lands which can accommodate the infrastructural provision envisaged.

(iii) The LNDR is adjoining the core of an established designated urban settlement, namely the City of Limerick, which acts as a centre for employment, retail, community, residential and transport functions.

(iv) The proposed LNDR will promote the compact and sustainable urban growth of Limerick City by facilitating enhanced access to employment centres such as the existing National Technological Park together with new centres of employment in due course. It will also provide significantly improved access to the University of Limerick's north campus, which still has significant development potential.

(v) There is no suitable alternative corridor for the proposed LNDR within areas which are at lower risk of flooding in the area adjoining the core of the urban settlement of Limerick; the selection of the identified route corridor was carried out using a balanced assessment methodology by applying the criteria of Economy, Safety, Environment, Accessibility and Integration. The Strategic Environmental Assessment Report for the proposed Variation expands on these criteria and details any likely significant effects expected as a result and where necessary the mitigation measures to address these effects. The selection process represents a detailed, robust, sequential approach, with the principle of avoidance of flood risk zones applied where possible, and which balances engineering and environmental constraints so as to select the most suitable route corridor.

7.3 Flood Risk Assessment

The required flood risk assessment has been carried out and is described elsewhere in this document. This demonstrates that the flood risk associated with the proposed LNDR can be adequately managed and the use or development of the lands to construct the LNDR will not cause unacceptable adverse impacts elsewhere.

The flood risk assessment concludes that a road within the proposed variation area can be constructed which will not exacerbate flood risk and will have a low residual flood risk. This can be achieved through suitable mitigation by appropriate sizing and configuration of bridge and culvert crossings of rivers, floodplains and streams intercepted by the road, together with suitable design of road drainage in accordance with the requirements of SUDs*

The proposed CFRAM Flood Protection Measures for the Annacotty-Mountshannon Area are presented in the CFRAM Preliminary Options Report for unit of management 25/26 (July 2016. The LNDR will not impact the implementation of these protection measures or reduce the design standard of the proposed protection. Furthermore, the proposed LNDR scheme will not be dependent on the implementation of the Flood Protection Measures to mitigate flood impacts.

The conclusion of the flood risk assessment is that the proposal to progress the LNDR project passes the justification test set out in the Flood Risk Management Planning Guidelines (Nov 2009), given the clear strategic nature of the proposed road transport development, the sequential approach involved in the route corridor selection process and the findings from the flood risk assessment that flood risk to the proposed road development can be adequately managed and mitigated for and that the construction and operation of the road can be engineered not to cause unacceptable adverse flood impacts elsewhere.

**SUDs – Sustainable Urban Drainage Systems*

8. CONCLUSIONS

The flood risk assessment identified two principal flood risk areas along the proposed corridor within the Limerick County Development area in which the proposed corridor has the potential to encroach Flood Zones A and B (High and Moderate flood risk areas). These identified flood risk areas are:

- The River Shannon at Ballyvollane, Mountshannon and Castletroy
- The Mulkear River at Annacotty, Mountshannon and Castletroy

Bridge crossings will be required at each of the above locations to accommodate the road scheme. The extent of known flooding history at each of the above crossing locations has been assessed and a determination of extreme flooding has been carried out. Based on this knowledge, the appropriate bridge opening width at each crossing location has been identified, as required to ensure that any changes to the existing flood regime will be kept to an acceptable level.

The proposed CFRAM Flood Protection Measures for the Annacotty-Mountshannon Area are presented in the CFRAM Preliminary Options Report for unit of management 25/26 (July 2016 . The LNDR will not impact the implementation of these protection measures or reduce the design standard of the proposed protection. Furthermore, the proposed LNDR scheme will not be dependent on the implementation of the Flood Protection Measures to mitigate flood impacts.

Recommendations

All watercourse crossings both culverts and bridges should be designed not to impede the flood conveyance through the structure and not cause any significant change in flood levels, flow depths and velocities that would result in any noticeable increase in flood risk or erosion/accretion either locally in the vicinity of the crossing or more remotely both in the upstream and downstream reaches.

Approval for all watercourse crossings will be obtained from the OPW under Section 50 of the Arterial drainage act 1945 in advance of tender and construction of the proposed scheme.

Road runoff storm outfall discharges to receiving watercourses should be designed not to exacerbate flooding by increasing peak flows. Mitigation of such impact from storm outfalls may require flood attenuation storage with the outflow controlled to greenfield runoff rates, particularly for the smaller watercourses where the contribution effect will be largest. Road drainage discharges to the larger Watercourses of the Shannon and Mulcair will not require attenuation as the storm discharges are miniscule to the flood volume in these rivers and the timing is that the storm water discharge will occur well in advance particularly for the Shannon.

The proposed road should be set at a minimum level that provides sufficient freeboard above the 100year with climate change flood event (Climate change allowance of 20% which for Ireland is generally equivalent to the current 1000year flood becoming the future 100year flood) so as to have a low flood risk over its design life and sufficiently elevated for its storm drainage system to function appropriately during flood events.

Where overbank flood areas have been identified, namely the Mulkear River and the River Shannon floodplains, overbank flood conveyance needs to be retained by providing sufficient overbank openings through bridge spans as not to significantly impede flood flows and produce an unacceptable increased in upstream flood level and flood risk to properties and lands.

The larger river crossings of the River Shannon and Mulkear at Castletroy should have a bridge soffit level with sufficient clearance above the 100year with Climate change flood to allow floating debris to pass underneath. The River Shannon Crossing and the envisaged Link Road Crossing of the Mulkear River should cater for navigation and boating requirements when defining the soffit level of the bridges. Refer to Figure 15 for summary of minimum flood Impact mitigation measures.

A Justification Test has been carried out in accordance with The Planning System and Flood Risk Management “Guidelines for Planning Authorities (November 2009). The conclusion of the flood risk assessment carried out is that the proposal to progress the LNDR project passes this justification test given the clear strategic nature of the proposed road transport development, the sequential approach involved in the route corridor selection process and the findings from the flood risk assessment that flood risk to the proposed road development can be adequately managed and mitigated for and that the construction and operation of the road can be engineered not to cause unacceptable adverse flood impacts elsewhere.